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LETTER

FROM THE

SECRETARY OF AGRICULTURE,

TRANSMITTING

A REPORT OF THE SPECIAL AGENT OF THE
DEPARTMENT OF AGRICULTURE FOR
MAKING EXPERIMENTS IN THE
PRODUCTION OF RAINFALL.

FEBRUARY 25, 1892.—Referred to the Committee on Agriculture and
Forestry and ordered to be printed.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1892.

IN THE SENATE OF THE UNITED STATES.

LETTER

FROM

THE SECRETARY OF AGRICULTURE,

IN RESPONSE

To Senate resolution of February 23, 1892, transmitting the report of the agent of the Department of Agriculture for making experiments in the production of rainfall.

FEBRUARY 25, 1892.—Referred to the Committee on Agriculture and Forestry and ordered to be printed.

U. S. DEPARTMENT OF AGRICULTURE,
OFFICE OF THE SECRETARY,
Washington, D. C., February 24, 1892.

To the Senate of the United States:

In compliance with a resolution of your honorable body, of the 23d instant, directing the Secretary of Agriculture to communicate to the Senate a copy of the report of the special agent of the Department of Agriculture for making experiments in the production of rainfall, I have the honor to transmit said report herewith.

I have the honor to remain, yours very respectfully,

J. M. RUSK,
Secretary.

The SECRETARY OF AGRICULTURE:

SIR: As special agent of the Department of Agriculture, for making experiments in the production of rainfall, I have the honor, in compliance with instructions contained in your letters, dated February 27 and June 30, 1891 (copies of which are hereunto annexed), to submit for your consideration the following report:

HISTORY AND ORIGIN.

It has long been sought to devise some means, whereby the blessings of rainfall may be somewhat equally enjoyed—that is to say, whereby there may not be distress from lack of rainfall, and whereby rainfall may be a blessing and not a calamity.

Many schemes, more or less rational, for producing rainfall, have been suggested. Among the earlier was one of Prof. Espy. In 1839, Espy suggested the building of great fires to heat the air, upon the theory that warm air, “rising, would, owing to the diminished pressure, ex-

pand, and, by expansion cooling the vapor, cause condensation and precipitation."

It was proposed in Australia, in 1884, after a drought had prevailed for three years, causing great industrial depression, to test Espy's theory; but Mr. Russell, the Government astronomer in New South Wales, declared that it would require the burning of 9,000,000 tons of coal daily, to increase the rainfall at Sydney by 66 per cent, where the average relative humidity is 73.

It has also been suggested to build fires along the margins of rivers or to erect a tall chimney over a pool of water and build fires at the edge of the water, with draft over the water up the chimney, causing the flames to pass over the surface of the water to the chimney, and thus carry moisture into the air. There is no doubt that this will form clouds of vapor in the air; but it is not equally certain that the vapor will be condensed to raindrops.

In 1871 Mr. Edward Powers published a book entitled "War and the Weather," being a collection of historical data tending to show that even in very dry regions, battles, during which there was cannonading, have been followed by copious fall of rain.

The theory that rainfall will be produced by concussion of the air, caused by explosions, is not new. Napoleon is said to have believed that rain usually followed heavy cannonading and to have taken advantage of this theory in ordering the maneuvers of his troops.

European scientists of a later day, entertaining the same theory, have pointed to the unusually wet season which prevailed throughout France during the Franco-Prussian war.

Quite recently, after writing my report, I have received from M. Charles Le Maout, of Saint-Brieuc (Côtes-du-Nord), France, five printed pamphlets, being essays by him, dated, respectively, 1856, 1861, 1870, 1886, and 1887, discussing the effect of concussion of the air toward the production of rainfall, and, by numerous illustrations, declaring rainfall invariably to result from heavy cannonading.

In addition to declared observations of rainfall succeeding battles, from concussion of the air from cannonading, attention has been called to the fact that during a shower, a heavy clap of thunder is always succeeded by an immediately increased fall of rain, even if this be but for a short time.

The proposition of Mr. Powers was to resort to heavy cannonading, and he estimated that the cost of two experiments, exclusive of the cost of the guns which were to be loaned for the purpose by the Government, would be \$161,500, or a little over \$80,000 each.

In 1880, Gen. Daniel Ruggles, of Virginia, obtained a patent on the production of rainfall by setting off explosives from balloons in the air.

The idea of producing rainfall by concussion, with the incident advantages to the world of rain where it is needed and such proper distribution of the rainfall that there might not be floods and torrents, made a strong impression upon the mind of Senator Charles B. Farwell, of Illinois. Considering the question of expense, however, it occurred to him, independently, and without knowledge that anything of the kind had ever been suggested, that a great saving might be effected with increased efficiency of operation, by causing the explosions to take place above the earth's surface, by firing high explosive attached to balloons. It seemed preferable to him to produce explosions somewhat above the surface of the earth, because of the closer proximity of the concussive force to the clouds, that is, to an apparent stratum or to apparent strata of moisture, or, if there were no clouds, still at a situation where the concussion would be most widespread, by not being impeded

by irregularities or obstacles on the surface, thus extending the area of concussion.

During the years 1888, 1889, and 1890, Senator Farwell frequently discussed with me the physical and mechanical questions involved in the subject, and, for the purpose of acquiring some knowledge of the present state of the art in meteorological science, I availed myself of the privilege of acquaintance with Lieut. John P. Finley, of the Army, who has long been connected with the Signal Service and whose work is well known, and also brought him and Senator Farwell together. In many interviews I obtained much specific theoretical information from him.

Impressed with the desirability of testing the question of producing rainfall by concussion, Senator Farwell obtained appropriations from Congress, at first of \$2,000 and then of \$7,000, which appropriations were accredited to the Department of Agriculture.

Senator Farwell having discussed the physical and mechanical details of the subject with me for a long time, as described, and I having undertaken some preliminary experiments at his expense, in 1890 and early in 1891, to test the ascensional force of various gases in different kinds of balloons, my name was brought to your attention, and on the 27th of February, 1891, I had the honor to receive from you the appointment as special agent of the Department of Agriculture, for the making of experiments in the production of rainfall, which appointment was continued June 30, 1891 to June 30, 1892.

PRELIMINARY INVESTIGATION.

At an early stage of the consideration of the subject, I discarded the idea of firing explosives from balloons. The plan having been to send up high explosives and set them off in the air, I thought it would be best to make the gas employed to carry up the balloon itself the explosive, and to employ a mixture of hydrogen and oxygen, in the proportion of about two of hydrogen to one of oxygen. This mixture of gases, upon ignition, explodes with great force and produces water, thus, perhaps, presenting (although the quantity is very small as compared with the volume of the gas mixture) a nucleus for the aggregation of more water.

But, upon suggestion from Senator Farwell, it was deemed best not to rely solely upon explosions produced above the surface of the earth, nor solely upon the effect of ignition of the gaseous mixture; and it was determined at the proper time to try the effect of explosions upon the ground and of the ignition of various other explosive substances from ordinary gunpowder (for the dense smoke resulting, which might supply nuclei for the aggregation of moisture) to the high nitro-explosives.

Immediately upon receiving the appointment, I addressed myself to the careful consideration of the subject, and, availing myself of the aid of the libraries of Congress and of the Patent Office, endeavored to ascertain what, if anything, had been done heretofore, knowledge of which might lead to benefit, either in the avoidance of any operation which had shown itself to be futile, or in the adoption of measures which would seem to have produced condensation of aqueous vapor in the atmosphere.

I found innumerable instances where heavy cannonading had been followed by copious fall of rain, though there was nothing definite to indicate that there might not have been rainfall in each case without the firing; and I also found an instance where a surface cloud is said to have been caused to disappear by firing:—a battery in France, going out and encountering a fog or mist, the firing of one or more of the guns

being said to have caused dissipation of the mist by condensation and precipitation of the vapor; but I could find nothing precise and authentic to serve as a guide for the details, when and in what manner to produce explosions in order to get any certain result.

THEORIES.

From about the time of the appointment until recently I have received many suggestions, entailing considerable labor of correspondence on my part; but the suggestions have been mostly as to possible theories (many of which I was quite unable to understand).

Among the theories advanced by those who maintain the practicability of producing rainfall by concussion, I mention the following:

First. That the jarring of the air by the concussive force of explosions causes aggregations of the particles of moisture held in suspension, particularly by the tendency of such a body as water to condensation, collection, or agglomeration, like quicksilver.

Second. That in connection with the jarring, smoke, particularly, perhaps, the smoke of gunpowder, presents nuclei or mechanical retaining points for the agglomeration of suspended particles of moisture, that moisture will collect in the air upon solid particles as nuclei being shown by the fact that hailstones are frequently found to have particles of dust or vegetable matter at their centers.

Third. That the reaction of the pressure of the atmosphere after each explosion, combined with the shock of the explosion, the buoyancy of the gases produced, and the heat generated, creates a forcible upward current, which breaks strata above and below, and takes the form of an eddy or whirlpool, which tends still further to break the strata and also extends the disturbance; or, with a shade of difference, that each explosion producing a momentary vacuum, the subsequent inrush of columns of air (considering the air, for mere illustration, to be in lateral columns) will, perhaps by the motion of the earth on its axis, not be just end to end or point against point; but, the columns passing each other, a whirl or whorl will be started which, widening as it extends upward, will present a vortex, whereby heavy or moisture-laden air will be drawn from afar, in right lines, toward the center, just as objects are drawn from the circumference of the maelstrom to its center; the action being thus centripetal and not centrifugal; the precipitation not necessarily waiting for an arrival at the storm center, but taking place as soon as there has been sufficient weight of moisture by condensation, anywhere away from this center, to prevent its longer being held in suspension.

Fourth. That electricity is generated by every explosion by the friction and other effects of the disturbances, and that this may be the factor in generation of storm-conditions by producing polarization of the earth and sky in the vicinity of the explosion, and a consequent magnetic field with a force tending to the gathering of moisture and the inducing of other conditions necessary for storm formation, electrical manifestation being a constant forerunner and concomitant of storms; and

Fifth. That, considering the distance between the place whence a moisture-laden air-current starts, or is finally launched, and the place where it parts with its moisture, as a straight line or a line of collimation, the actual track of the current or the path of the moisture will be curvilinear—just as the trajectory of a projectile is a parabola—that, as a very slight obstruction, opposed to a projectile under even very great velocity, will greatly aid the force of gravity in deflecting the

projectile toward the earth, that is, shortening the curve, so, opposing waves in the atmosphere, produced by explosions, will tend to shorten the path of the current, and that if this moisture-laden current then meets a cold current, precipitation of the moisture upon the earth will be immediate; that the moisture-laden current passing from the Pacific Ocean eastward is deflected upward by the Rocky Mountains to such an extent that its trajectory from that place—the place whence the current is launched—is very long, so that the current does not get within reaching distance of the earth until it has passed over what are called the arid regions; that the cause of precipitation of moisture toward the end of the trajectory is by reason of contact of the moisture-laden current with the north current, and that if the moisture-laden current can be brought down sooner precipitation will take place at a shorter distance from the upward deflecting surface, or the mountains. The objection that the moisture-laden current will be at least as liable to meet a cold current or conditions of low temperature at high altitudes, and so have its moisture condensed there, is met by the statement that if the moisture be condensed, even congealed to frost or to ice particles so high above the earth's surface, it may still be carried onward to a great distance by its vehicle, namely, the current of air, before it gets below this vehicle, and, even after having dropped therefrom, may be completely absorbed by dry air below, before reaching the earth; so that the point of this theory would seem to be to bring down the moisture-laden current.

PREPARATORY WORK.

Without any theory or theories on the subject myself, I understood your appointment to mean that I was to consider and formulate, and adopt or devise the most practical and reasonable means to ascertain whether violent and sudden motion or concussions, produced upon the air by explosions, can have any effect toward the production of rainfall.

Therefore, in the preparation of this report I have confined myself, as far as possible, to a mere statement of facts, together with such a review of past information as may be useful in giving weight to previous investigation, concluding with deductions that seem to be justified by the observational and experimental knowledge obtained.

I determined to proceed in a purely empirical and, so far as my judgment would extend, practical manner; and the first step was to ascertain what would constitute the best explosives. My knowledge of explosives and their action was somewhat aided by early military training, some military experience in time of war and subsequent thereto, and connection with the subject of explosives as chemist in the United States Patent Office.

Early in March I went to New York City and spent some days in going around among the manufacturers of high explosives, and procured samples for test. I also procured a number of paper balloons and some paper bombs.

Returning with these I made the necessary tests at my country place, Laurelwood, at Mount Pleasant, in this District, a short distance from the city of Washington. I found the balloons entirely unsatisfactory, because the paper was not gas-tight. I found the preferable explosive for the purpose to be rackarock, which, consisting of two ingredients, non-explosive when separate, and thus very safe and transportable as ordinary freight, is of high explosive force when the ingredients are properly mixed, though even when ready for explosion it is less sen-

sitive and so less dangerous than dynamite and the other common nitro-explosives; and I became satisfied that the bombs, if fired in sufficient quantity and made of somewhat larger size than I was able to obtain, might be effective.

In the meantime I had begun correspondence with all the balloon manufacturers in the United States of whom I could learn, in order to get the prices of balloons of various sizes and materials, adapted for use for inflation with oxygen and hydrogen gases, and to be exploded at high altitudes.

As a result of my correspondence, upon the morning of March 9, a balloon manufacturer and practical aeronaut, of New York State, arrived at Washington, bringing samples of fabric and paper for balloon construction and also parts of apparatus for the manufacture of oxygen gas. He and I, together with Dr. Claude A. O. Rosell, of the Patent Office, an eminent chemist, who was subsequently detailed by the Secretary of the Interior, upon your request, at my suggestion, to aid me in making the experiments, tested the oxygen apparatus and carefully discussed the questions of size of balloons, and of the material from which they might most advantageously and economically be manufactured.

The balloon manufacturer was directed to return at once to his place, where, having facilities for manufacturing and sending up balloons of all sizes, he should experiment with the various fabrics and papers and also with small quantities of the explosive mixture of gases proposed, and should report to me when he had arrived at something definite, whereupon I would, myself, go there to experiment and make observations before ordering a large quantity of apparatus and material for making the more important experiments in the District of Columbia and elsewhere.

During the next few weeks experiments were made on the lines proposed, and I made search in New York City and at other points, for a paper or material for manufacturing paper suitable for the construction of balloons of 8 or 10 feet in diameter. The use of paper for the purpose would greatly reduce the cost of balloons, but no practical way of obtaining a paper that would answer the requirements was found. With more time for investigation, however, I have no doubt that a suitable paper can be provided, and believe that a paper properly made from the pulp obtained from the destroyed Treasury notes or national currency—the so-called greenback pulp—would answer the purpose.

During March, I was also engaged in considering various apparatus and devising plans of operation.

On the 5th of April I went to New York State with an assistant and spent several days with the balloon-maker, making experiments in producing concussions by means of various explosives, especially with the mixture of oxygen and hydrogen gases. This mixture was found to produce a very powerful explosion and concussion of the air, and the balloon-maker was given an order for the following material and apparatus:

Twenty 10-foot balloons, constructed of fine muslin, woven especially for the purpose and supplied by special apparatus with a number of very thin coats of varnish.

Twenty retorts or canisters, with proper fittings for manufacturing oxygen.

One gasoline furnace for the same.

Fifty electrical fuses.

One 20-foot balloon.

One electrical discharger.

One hydrogen generating apparatus, complete.

Five oxygen wash-bottles, with connections; and some dynamite.

Later, more balloons, etc., were ordered.

A balloon 10 feet in diameter will, including the neck, contain about 525 cubic feet of gas at 30 inches of the barometer; a 12-foot balloon, about 1,000 cubic feet; and a 20-foot balloon, about 4,500 cubic feet.

During April and May the manufacture of balloons and the construction of other apparatus were rapidly pushed, and, with the assistance of Dr. Orazio Lugo, of New York, Dr. Rosell, of the Patent Office, and Mr. John T. Ellis, whom I called from Oberlin College, Ohio, to act as my assistant, I thoroughly investigated the different processes of manufacturing the gas, etc., finally deciding upon the use of sulphuric acid, water, and iron, for hydrogen, and chlorate of potash and black oxide of manganese, subjected to high heat, for oxygen, and had the various necessary apparatus constructed. Investigations were also made as to the most economical and advantageous sources from which to obtain the necessary chemicals and supplies, freight and other expenses being considered.

On the 13th of June I sent Mr. Ellis to New York State, where he spent several days with the balloon-maker at his place, and in New York City on his return, inspecting the apparatus which had been constructed and making final arrangements for a preliminary test in the District of Columbia during the following week.

Some time was spent in looking about for clean and suitable iron borings or scrap as free as possible from grease, and many establishments in the United States, which would be likely to have such, were written to for prices and other information.

It also occurred to me that kites might be employed for suspending in the air high explosives, such as nitro-glycerine or nitro-gelatine, in suitable pouches of fabric, or dynamite or other solid explosives, in sticks or parcels, though the idea of employing nitro-glycerine or nitro-gelatine was subsequently abandoned as too dangerous and as troublesome in use, the operation being confined in this particular to the employment of dynamite and rackarock.

I considered that kites might also be serviceable to act as condensers to collect and convey to the earth any appreciable atmospheric electricity. I thought that if the explosion of the gas mixture or of other substances employed, generated static electricity by the concussion or by friction of bodies of air, then, by having a suitably prepared kite within proper distance of the exploding balloon, the charge might be collected and possibly measured. It seemed, also, that the kites might be employed to ascertain atmospheric electrical conditions before and after, as well as at the time of explosion. For electrical purposes it was clear that the faces of kites should be supplied with strips of tin-foil properly in contact with a suitable light, insulated, two-conductor wire, and that the wire might, at the earth, be in connection with a sulphuric acid or other suitable condenser, the kites also to have collecting knobs of coils of wire at their corners. But simple as the making and flying of a kite may appear, every boy being an adept in the art of kite-flying, it is not so easy to determine just what form of kite would be suitable for my purposes, and I undertook and engaged in many experiments in which I received assistance from the balloon-maker. The handling of large kites with long tails was found to be exceedingly troublesome, and the preparation and transportation of this balancing weight was a serious matter, considering the question of time and labor.

As a stiff breeze tends to carry kites out horizontally and keep them from rising when hung as usual, a hanging or poise was adopted which would tend to make the kite ride the wind; and, in order to get a greater elevation than can be got with one kite, owing to the weight of the connecting line or wire, I determined to send some kites up "tandem," whereby intermediate kites between the end kite and the ground, the intermediate kites having short lines attached to the main lines, would act as buoys to lift the main line.

I ordered a large supply of sticks and of fabric, and other adjunctive matter from which to make a number of kites, varying in height from 3 to 12 feet, regard being had in the manufacture to the economical cutting of the material. It was found that some of the kites could be made tailless.

In addition to the other work, I had spent some time in prospecting over the District of Columbia for a suitable site or place where the apparatus might be set up and tested, and a few balloons be exploded to get some idea of the concussive effect. Since a soap-bubble filled with two parts of hydrogen to one of oxygen will explode with a report as loud as that of a horse-pistol, it was not known what might be the effect of the explosion of hundreds or thousands of cubic feet of the mixture, and I did not deem it wise to explode a balloon filled with the mixture at any place except where there might be ample room and freedom from habitations. An experiment made many years ago by Prof. Joseph Henry, of the Smithsonian Institution, in which he had exploded less, I believe, than 50 cubic feet of the mixture, compressed and in a vessel buried in the ground, had resulted in what seemed like an earthquake on a small scale, and had, I am informed, torn a hole in the ground some 18 feet in diameter. In addition, it was necessary that the place should be of ready access for the carriage of the material and apparatus thereto. It was also necessary, for the manufacture of the hydrogen, that water should be within convenient distance, and it seemed best to choose a somewhat secluded place for operation in order to be undisturbed. I finally ascertained that the most suitable place was a field hidden from the road by a grove of trees and on a hillside running down to Piney Branch Creek, near my place in the country.

PRELIMINARY TESTS.

On the 17th of June, Mr. Ellis returned to Washington with the balloon-maker and an aëronaut and aëronautical mechanic, Mr. George E. Casler. Unsettled and rainy weather during the next succeeding three days prevented any outdoor work, but plans and methods were fully discussed here with me.

On the 20th and 21st, a small hydrogen-generator, an oxygen apparatus, and sufficient material to inflate a number of balloons were taken to the field on Piney Branch, and some things stored in the buildings on my place, and on the 22d one balloon was inflated and sent up captive with duplex insulated, or so-called two-conductor, wire (No. 21) holding the balloon at the neck and also connected to an inserted electrical cap or fuse, and exploded at an altitude of 1,850 feet above the top of the hill, from the electrical discharger or dynamo on the ground. The appearance of the explosion was that of a disk of fire extending laterally and of a diameter of about 20 feet, with irregular lance-like edges, and immediately afterwards a slight nebula was visible for an instant. The report was terrific and was heard all over the District of

Columbia, and the concussive effect was far-reaching and quite markedly felt by those on the field. The crash is said to have been greater than that of any peal of thunder, as appears from the following letter:

SMITHSONIAN INSTITUTION,
Washington, D. C., June 23, 1891.

SIR: Permit me to enter a protest against a continuance of the experiments in firing the balloons on the property adjoining my farm and residence. I have a herd of very fine Jersey cows, some with calf, and the tremendous explosion yesterday right over my barn was calculated to cause abortion. I have had this happen from a thunder storm and your bomb was worse than any thunder. It shook the house and alarmed my family.

Please, Mr. Secretary, move your dynamiters away from "Oakmont," Piney Branch.
Yours, respectfully,

WILLIAM J. RHEES,
Chief Clerk, Smithsonian Institution.

Hon. J. RUSK,
Secretary of Agriculture.

This and the subsequent experiments were undertaken for the purpose of testing and studying the operation of the apparatus and learning some practical details, and being performed at a time when rains were frequent, the circumstance of succeeding rain was not heeded. In fact it was not supposed that one explosion however great or a few explosions at long intervals, would be effective toward inducing the presence of rain clouds, since many instances are known of the explosion of a powder-mill without the explosion bringing rain.

On the 24th a series of experiments, consisting in the inflation and explosion of several 10-foot balloons (at rather long intervals, owing to the inadequacy of the oxygen-generating apparatus), was made in the presence of a number of prominent officials and scientists. The chief purpose of these experiments was to ascertain whether a smaller proportion of oxygen might not suffice, as I had recognized that the ready production of oxygen in large quantity was a difficulty with which we would have to contend.

The explosions at these experiments were considered by those who were present, as of great intensity and volume and as very violent, but I recognized that no one of them was much more than half equal in force and sound and concussive effect to the explosion at the first experiment. This was clearly owing to the diminished proportion of oxygen. In the case of the explosion of one balloon the proportion of oxygen had been so diminished that the excess of hydrogen took fire and set fire to the fragments of the balloon, which then fell blazing through the air.

The experiments were attended with some difficulty, owing to a rather strong wind which prevailed, and a balloon, held captive, would not rise straight upward, but would be blown out horizontally after diving toward the ground as a gust of wind struck it. This showed me that in employing balloons I should sometimes have to let them be free and employ common time-fuse with a percussion or fuse cap to fire them.

In this series of experiments, the combination of the explosion of dynamite with that of balloons (two sticks of dynamite being placed in a balloon with the electrical cap in the dynamite, the explosion of the dynamite to set fire to and explode the mixture of gases) was tried; but the appearance was not different from and the report seemed little, if at all, greater than that from a balloon without dynamite. It seems noteworthy that explosions in the air do not appear to have the concussive or jarring effect upon objects on the earth which even more distant explosions on the ground have upon these objects on the ground, so

that I have never heard of a mere peal of thunder, however loud, breaking glass in windows, while the discharge of a 6-pounder gun with less noise will do this.

As the gas mixture and the dynamite placed together did not produce any markedly increased effect, I considered that additional expense in setting off these different explosives together in the air would not be justifiable. I determined from this to fire the gaseous explodent alone in the air, and whatever solid explodents were to be employed, near to or upon the ground.

In addition to what has just been described as having been done in this series of experiments, two balloons filled with the mixture of oxygen and hydrogen were sent up, connected "tandem," about 100 feet apart, by electrical conductors, and were fired from the one dynamo on the ground. Both balloons were exploded, and there was an appreciable interval between the explosion of the first and that of the second balloon.

The apparatus for the manufacture of the gases was found to work fairly well, except as to certain minor details, and provision was made to remedy defects before proceeding further. The production of oxygen, however, in the quantities necessary for practical operation was found to be an exceedingly difficult problem, one scarcely soluble without obtainment of apparatus too expensive for the smaller appropriation to afford. I had to wait, therefore, for the next appropriation to become available, but set to work at once with Mr. David H. Mead, of this city, Dr. Rosell, and others to devise a suitable apparatus for manufacturing oxygen on a larger scale and with more certainty. The apparatus devised will appear in some of the photographs taken at Midland, Tex., and will be pointed out later on. It was proper in principle and, if properly made, would have answered every purpose, but made by a firm in this city, it was defective in construction.

In accordance with the order contained in your appointment, I had notified Gen. Daniel Ruggles, the patentee, to be present at the experiments of the 24th, and I paid his expenses out of the appropriation.

Among those present at this trial of the apparatus were Hon. Edwin Willits, Assistant Secretary of Agriculture; Assistant Secretaries of the Treasury Nettleton and Spaulding; Prof. Langley, of the Smithsonian Institution; Maj. J. W. Powell, of the Geological Survey; the Commissioner of Patents, Gen. Daniel Ruggles, and about fifty other scientific and practical observers.

WHERE TO GO.

The next consideration was where to make the test for rain. It was not difficult to decide where not to make this test; for it was clear that operations in a rainy climate like that of Washington and its vicinity and during an unusually rainy summer like last summer would prove little or nothing, at least until some initial knowledge should have been obtained. From the time that the fact of the appropriation and my selection as special agent had become known, I had received many urgent solicitations from various rainless regions to go there and make trials. But all the places to which I was asked to go were not only very far from Washington, but most of them were rather inaccessible, and the items of transportation to and of labor and assistance on the ground would have been very great. At this point, I received a generous offer from Mr. Nelson Morris, of Chicago, of the freedom of his large ranch in the dry region of Texas, with supply, gratis, of assistance, free subsistence and quartering of the expedition, and payment of local expenses, and I accepted the offer.

The ranch, known as the "C" ranch, is near Midland, a town in the Northwestern part of the State and a station of the Texas and Pacific Railroad, and embraces several hundred thousand acres (so there would be no want of room); but the ranch house, located in the south central portion of the Llano Estacado, in Andrews County, a county adjoining New Mexico, on the west, is 23 miles from Midland, much farther than I had been led to believe.

A short time before leaving Washington, while looking for a competent meteorologist, Mr. George E. Curtis was recommended to me by Prof. B. E. Fernow, chief of the forestry division of the Agricultural Department, as a competent man, and, upon Mr. Curtis then calling upon me, I employed him, at a stated per diem, to act as meteorologist of the expedition during the operations near Midland. Mr. Curtis was not able to leave Washington at the time at which I left and it was understood that he could not be absent from Washington longer than about three weeks.

At the request of Mr. Curtis, I bought a self-regulating Richard frères barograph, and he obtained, through the courtesy of the Weather Bureau, a delicate aneroid barometer compensated for temperature, stem-graduated thermometers, tested and supplied with correction cards, two sling psychrometers, and a Robinson anemometer.

From the Blue Hill Meteorological Observatory, Readville, Mass., through the courtesy of A. Lawrence Rotch, esq., director, I was furnished, free of charge, with several sulphuric-acid condensers. Nowhere, however, could I find suitable electrical measuring apparatus for an instantaneous static charge, although I made search in New York, and afterwards in St. Louis, for the same.

Mr. A. E. Porter, manager of the Smith Electrical Works, Pompton Lakes, N. J., lent me, without any charge whatever, eight magneto machines, that is, electrical dischargers or so-called dynamos, for use in the experiments; and these dischargers, of the most perfect construction, were of great service. By this public-spirited act on the part of Mr. Porter and his company an amount of not less than \$230 was saved to the appropriation.

THE START FOR THE FIELD.

On the 3d of July the apparatus, which had been completed, and two tons of cast-iron turnings from projectiles, furnished by the Navy Department, were shipped by freight to St. Louis, en route for Midland and I sent Mr. Ellis to St. Louis to make arrangements for securing other materials and necessary chemicals in that city, as I had ascertained that they could be obtained there with economy, considering freight charges.

In St. Louis there were bought from Meyer Bros. Drug Company, 8 tons of sulphuric acid in drums, 1 ton of chlorate of potash in kegs, 500 pounds of binoxide of manganese, and a number of casks for use in connection with the hydrogen apparatus, arrangement being made for the return of the unused material and empty condensers. From George E. Fritz & Sons, and other houses in St. Louis, there were purchased 5 tons of cast-iron borings and other miscellaneous materials necessary.

By reason of delays on the part of certain firms in New York, in the construction and shipment of special grades of wire and kinds of explosives, and of delay on the part of firms of this city in the completion of an oxygen apparatus, it was necessary for Mr. Ellis to wait in St. Louis until the 24th of July. Upon their receipt, on that day, they were loaded into a freight car, together with the materials purchased in St. Louis, and were shipped to Fort Worth, Tex.

Meanwhile, through the public spirit of the St. Louis, Iron Mountain and Southern Railroad and its attention to Southwestern interests, and by the courtesy of Mr. George C. Smith, free transportation had been obtained to the amount of \$500.

On the 26th of July Mr. Ellis proceeded to Fort Worth and Dallas, where, by the kindness of Mr. John A. Grant, general manager of the Texas and Pacific Railroad and the interest of the road in the welfare of Texas, free transportation was obtained for the members of the expedition and the apparatus to the amount of about \$300. The carload of apparatus was then shipped to Midland, arriving on the 5th of August.

Before I left Washington I desired to gain some further knowledge on the subject of explosives, and thought that I might with benefit consult with some of the officers at the artillery school, Fort Monroe, Va. With this object in view I went there, at my own expense, about the middle of July, but learned nothing new except that there is a very large quantity of powder stored at Fort Warren which is unserviceable for military purposes, but which might be available for producing explosions in rainfall experiments. Subsequently I had an interview with the Assistant and Acting Secretary of War and discussed with him and with an officer of the Ordnance Corps, the possibility of obtaining a supply of this powder, but without coming to any determination, and as I was occupied with many other matters connected with the expedition, and busy in getting the remaining material together for proper shipment, I did not pursue the subject further. I suggest, however, that this unserviceable powder might be employed advantageously in rainfall operations in the future.

July 29, the balloon-maker and Mr. Casler arrived at Washington with the remainder of the balloon apparatus and various appurtenances, and on the 30th, accompanied by them and Mr. Paul E. Draper, I started for Midland, Tex.

The route to Midland was by way of St. Louis, Little Rock, Texarkana, and Fort Worth. Arriving at St. Louis, I spent a day there in the collection of some small supplies, and had a block of pure tin rolled into thin sheets for the electrical kites.

At Thurber, Tex., I met Mr. R. D. Hunter, who generously sent from his coal mines to Midland, six kegs of blasting powder for use in the experiments.

I reached Midland on the evening of August 5, in company with Mr. E. W. Rannells, the manager of Mr. Morris's ranch, who had joined me en route, and on the following day most of the party were taken in various conveyances to the headquarters of the "C" ranch. Mr. Ellis had arrived at Midland on the 4th. The ranch house is about 6 miles north and 17 miles west of Midland, say, in latitude $32^{\circ} 12' N.$ and longitude $102^{\circ} 20' W.$, and the elevation above the sea level is about 2,800 feet.

There had been a deficiency of rain in this region for several years, as I was informed, and during the past eighteen months the drought had been especially severe.

The journey of 23 miles from Midland Station to the ranch house made a strongly negative impression upon me, as regarding the possibility of obtaining any rain in that region. The day, described to me as a typical day there, was a very hot one. Though we started quite early in the morning, the sun shone fiercely. There was not a fleck of a cloud visible anywhere in the sky. The ground was dry with the appearance of alkali and seemed parched. The landscape was a general glare. There was a strong dry wind from the south, which seemed

greedily to take up any moisture that might be present as on the skin, leaving the skin with a feeling of parchment. I was assured that this was but one of a succession of scores of such days at this time in the morning; though later in the day, light summer clouds, ball of cotton or light cumulus clouds, were wont to make their appearance.

While I would not perform the experiments in a wet climate, because I felt that, if rain followed, the fact would not be satisfactory in the sense of a result, and that this would be no fair test, on the other hand, during my ride from Midland, I feared that I had here gone to the other extreme, and that the test would not be fair either; that no local disturbance under such conditions as here existed could induce the presence of moisture; and this doubt became rather a conviction as day after day of the same kind succeeded.

IN THE FIELD.

August 7 and 8, Mr. Ellis and Mr. Casler, with men in the employ of Mr. Nelson Morris, were engaged in unloading the car, and on the 7th, four large wagon loads, some by double teams, were hauled to the ranch. On the 8th, the remainder of the apparatus and material was loaded and hauled out, excepting 6 drums of acid (9,600 pounds) and some iron (8,000 pounds), which material was stored at the freight depot. The help and cartage were generously supplied by Mr. Morris.

At Midland I ordered two large tanks to be built, that we might make hydrogen more rapidly and on a larger scale.

On the 7th, being myself out at the ranch, I rode over the ground for a mile and a half to the south of the ranch house and for about a mile to the east and west thereof. The region being entirely without stream or natural pool, every ranch is supplied with numerous wells from which water is pumped into surface tanks or ponds by wind-wheel pumps. Here and there are extensive depressions, called by the herders "draws," which, being dry, showed white alkaline efflorescence.

I deem it proper, at this point, to state that, notwithstanding the barren appearance of the region, the soil seems exceptionally rich and strong, even on the knolls. This may be from the fact that the soil here is not leached nor are the knolls denuded of topsoil by great rainfall. In spots where the land is artificially watered the soil is very highly productive. I was particularly impressed with the abundance and size and the fine quality and flavor of fruit grown at and about Midland, the peaches and pears being very fine, and watermelons weighing more than 70 pounds being common. If the region could only be supplied with water there would be little left to be desired there.

I determined to place my material in three parallel lines somewhat less than half a mile apart, the lines being concave toward the ranch house, and extending to about equal distances to the east and west thereof, the ranch house being about the center of the position. In the front line, that is, in the line farthest to the south of the ranch house, namely, in the front thereof, between the ranch house and Midland, at a distance somewhat less than 50 yards apart, I placed about sixty short guns, something like mortars, improvised from 6-inch well tubing sawed into lengths of about $2\frac{1}{2}$ feet, and from bell-mouthed wagon-axle boxes, all of which were set with one end in the ground at an angle of about 45° , leaving the outer end free; and, in addition, I made several mines or blasts by putting sticks of dynamite and rackarock into prairie-dog and badger holes. The mortars were afterwards loaded with the blasting powder kindly given me by Mr. Hunter, sod and earth rammed

down hard, supplying the wadding, and blasting fuse inserted from the top or bottom, as was most convenient, or electrical-fuse caps, affording the means through which to ignite the charge. Where electrical-fuse caps were employed, the gun was to be fired from an electrical discharger. The setting of these tubes, or guns, was a matter of considerable labor and consumed much time, as the ground was very hard.

On the next line I intended to place kites, each kite to be in a position directly in the rear of the central point between the two guns in front of it; and on the rear line—a line, however, much shorter than either of the other lines—and behind the house, I desired to send up and explode balloons.

The tubes were not all set at one time, some being set on the 13th, 14th, and 15th.

The whole party engaged at different times in making the kites, and, as they were completed they were carried out to their positions.

As it would have required a large force of men to fly all these kites, if each kite had to be held by a man, it was intended to fasten them to the mesquite bushes, the chapparal bushes, and the catsclaw bushes, with which the prairie is scantily supplied.

The reason that I chose the rear line for the balloons was that there is a kind of meadow in the rear of the house, extending more than a mile to the left, or east, thereof, and some distance to the right or west, and, being supplied with grass and being free from the thorny bushes, there would be less danger of tearing any balloon in inflating it, or in transporting it from the place where it had been inflated to the place where it might be desired to let it rise. There is a well at the ranch house; but the water is very alkaline, and I feared that the use of this water in making hydrogen might entail loss of acid or detract from its efficiency by some neutralization; and so I deemed it best to set up the hydrogen apparatus at a well on this meadow, where the water is less alkaline, about a mile to the left, east-northeast of the house; it being intended to inflate the balloons there, send up some from that place, and carry the rest to the westward along the meadow.

The ranch house is shown in the accompanying photograph marked I:

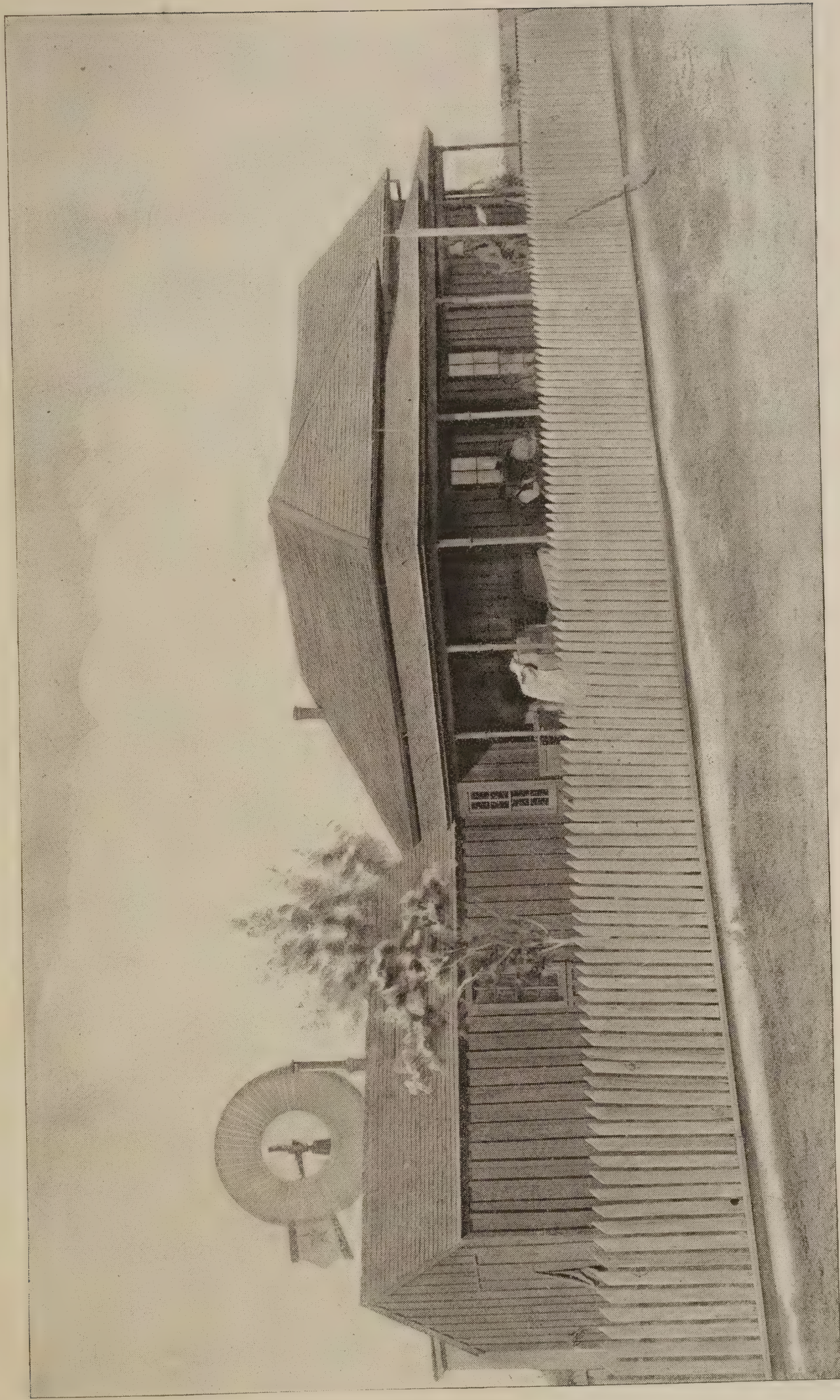
The well which I chose for the situation of the hydrogen apparatus is shown in the annexed photograph, marked II, where, also, may be seen the hydrogen apparatus in operation, with a balloon in process of inflation.

On the 9th of August I was joined by Mr. Powers, author of "War and the Weather," whom I had invited, at the expense of the appropriation, to be present at and assist in the experiments.

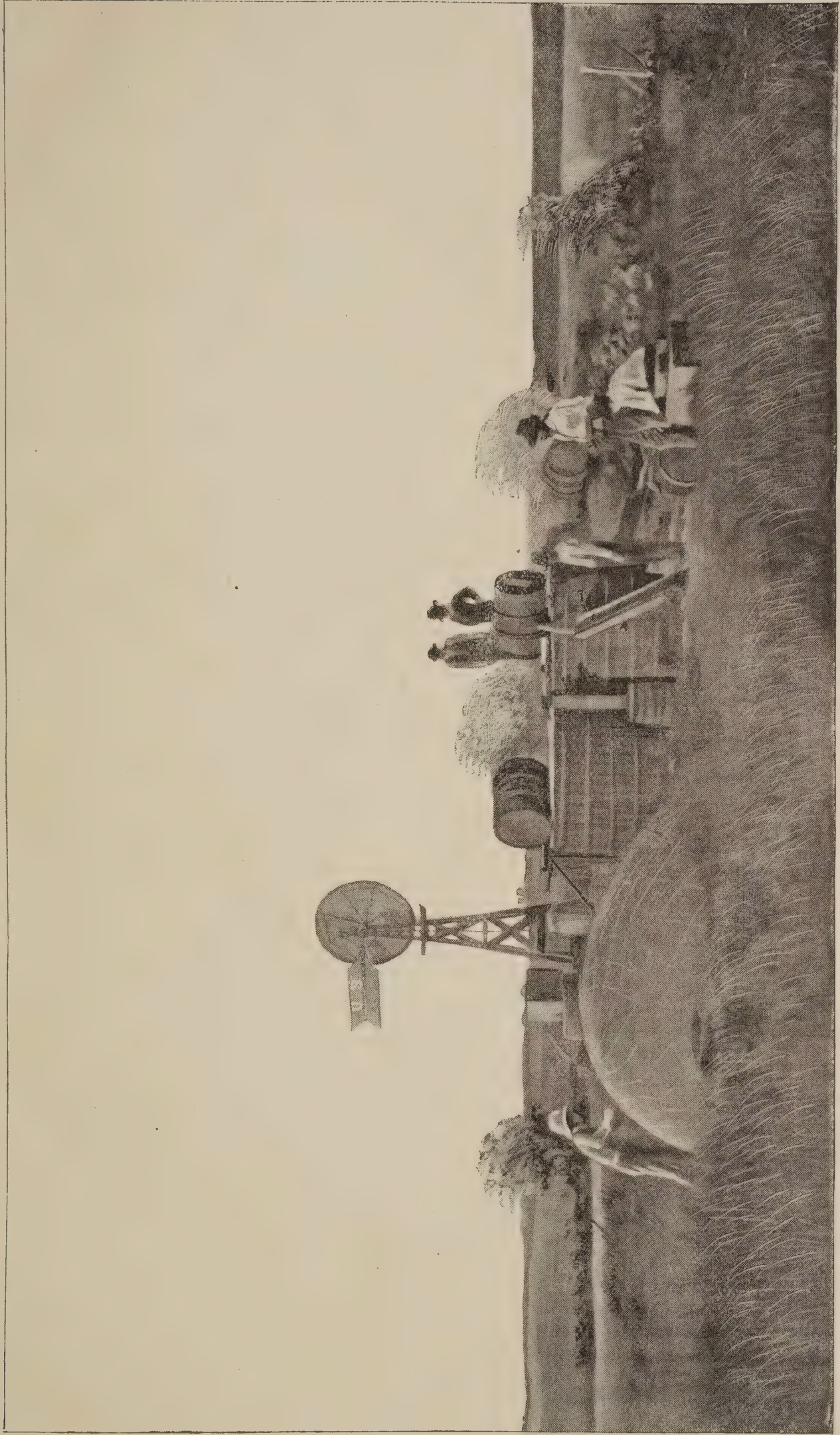
On the evening of this day, August 9, a trial of the power of the "rackarock" was made, at which a number of charges were exploded and the force was found to be very great. There was great concussion. The explosions were made at about a mile to the southeast of the ranch house, and there was a strong wind blowing from the southwest.

On the morning of the next day, August 10, a very heavy rain fell, coming from the northeast and extending west and southeast. The rain continued for about two hours, causing water to run into the "draws," and the plains to be drenched. The amount was not accurately measured, as I was not yet prepared; but it was estimated at about an inch.

Maps of the Weather Bureau being received later, it was seen that on the map of August 7, 8 p. m., the forecast to 8 p. m. of August 8, predicted light showers *on the Gulf coast* of Texas; that the map of



I. The Ranch House.



II. The Well or East Mill.

August 8, 8 a. m., showed a shower at Palestine, toward Galveston, in the preceding twelve hours, the wind being northwest; no rainfall at Abilene nor west of Abilene, Abilene (Weatherford) being the nearest weather station to Midland, and about 140 miles east thereof, and Palestine being farther from Abilene (direction east by south), than Galveston is from Palestine (direction south by east); that the map of August 9, 8 p. m., showed a Gulf rain extending, on the south and east, from Galveston to New Orleans, and, on the north and east, from west of Palestine to Vicksburg; no rainfall at Abilene nor west thereof; that, on this same map the forecast to 8 p. m. of August 9, predicted showers in the eastern portion and on the coast of Texas; that the map of August 9, 8 p. m., showed a rain in the eastern portion and on the coast of Texas, the rain not extending so far west and northwest as that shown on the map of August 8, 8 p. m.; that, on the map of August 9, 8 p. m., the forecast to 8 p. m. of August 10, predicted local rains in the southeastern with fair weather in the northwestern portion of Texas; that the map of August 10, 8 a. m., showed a local rain at Abilene in the preceding twelve hours, the wind being south (the actual time of the rainfall was between 12:20 a. m. and 4 a. m. of the 10th); and that the map of August 10, 8 p. m., showed clear weather at Abilene and vicinity from 8 a. m. to 8 p. m. of the 10th.

At the time that the rain came at the ranch it seemed that the explosions might have had some effect in producing the storm; but when I learned that there had been a heavy shower at Abilene that morning I attached no significance to the heavy rain at the ranch as resulting from the explosions.

But I found it to be of common knowledge along the Texas and Pacific Railroad that while rains are not infrequent at Abilene and even as far west toward Midland as Big Springs (only 39 miles from Midland), it will rain at these places time and again without the rain falling at Midland and vicinity; and I was also soon informed by many persons from Midland and vicinity, and by the most experienced and observant herders on the ranch, and ascertained it to be a fact, that it was a common sight to see heavy rain or *nimbus* clouds, evident rain storms, passing over the locality, on their way somewhere else, and without parting with a drop of water to this ground; and it occurred to me that I might have observed the reason for this during my ride from Midland station. The ground is so heated and dried by the sun and the dry wind that, by radiation, a very thick stratum of superincumbent air is kept hot, and this exerting a repellent action no moisture can be precipitated. The dry stratum may even take up considerable moisture from above without letting it get to the ground. One might as well expect moisture from the upper part of a steam-filled room to be deposited on a hot stove therein. There is no dew at night in this region. There can not be, because the ground is warmer than the air. That is to say, there is no dew unless the ground has been cooled by a rain or a norther, and it does not generally remain cool enough for moisture to be deposited longer than one night. Unless the rain clouds are very heavy, it would seem that the hot and dry layer of air would have to be broken up ere there can be precipitation of moisture upon the ground, and it may be that the explosions of the 9th broke up such a layer by a widely extended displacement and replacement, with commingling of air currents.

In this connection I wish to mention a phenomenon observed several times from the ranch-house porch, facing south. The southerly wind, bringing cumulus clouds toward us, they were often, at low altitude, seen to vanish as they approached, thus showing the conversion

or reconversion of moisture into vapor, probably through the influence of the dry and heated surface-stratum of air.

A very interesting and singular climatic feature observable in this region is, that the surface currents are very much more rapid than the higher currents, which are sometimes of different directions, as evidenced by the motion of clouds, and, as will hereafter appear, by the motion of balloons.

On the evening of August 11, Mr. Curtis arrived at the ranch house.

On the next day Mr. Curtis set up the anemometer, at about 100 feet from the ground, placed the pressure and heat-measuring instruments in suitable situation, and instituted a regular system of observation, taking observations daily at 7 a. m., 2 p. m., and 7 p. m., central time. He was most exact in the time of his observations. I am sorry that he was with the expedition so very short a time, arriving after the first rain and leaving before the heavy Midland experiment. Mr. Curtis has made me no narrative report; but, upon my calling on him for a report, has furnished me with the following tabular statement:

Report of tri-daily observation made August 12 to 24, 1891, at the "C" ranch, 16 miles north and 12 miles west of Midland, county of Andrews, State of Texas.

[Latitude, 32° 14'; longitude, 102° 12'. Local time is forty-nine minutes slower than Central time, hence 7 a. m., Central time = 6^h 11^m a. m. mean local time; 2 p. m. Central time = 1^h 11^m p. m. mean local time.]

Date.	7 a. m., Central time.			2 p. m., Central time.			7 p. m., Central time.		
	Temperature.		Dew point.	Temperature.		Dew point.	Temperature.		Dew point.
	Dry bulb.	Wet bulb.		Dry bulb.	Wet bulb.		Dry bulb.	Wet bulb.	
August 12.....				87.5	66.1	55	79.3	66.8	61
August 13.....	68.5	64.0	62				87.7	65.1	52
August 14.....	68.0	64.2	62	90.0	68.6	58	89.0	63.6	48
August 15.....	71.0	61.4	56	92.7	66.4	52	89.0	64.4	50
August 16.....	69.8	63.4	60	88.0	69.5	60	85.0	67.0	58
August 17.....	69.8	62.6	59	89.9	69.1	59	83.8	68.9	62
August 18.....	71.6	66.6	64	85.0	69.0	62	73.9	67.8	65
August 19.....	70.9	66.9	65	91.0	70.3	61	90.0	68.6	58
August 20.....	76.0	65.4	60	96.0	69.6	57	82.0	66.0	58
August 21.....	68.8	62.6	59	95.8	69.6	57	93.0	66.4	51
August 22.....	62.6	60.1	58	65.7	57.6	52			
August 23.....	51.0	47.5	45	78.4	57.4	41	75.3	55.2	39
August 24.....	60.4	51.4	44	88.9	63.6	48			

Date.	Precipitation.			Wind.					
	Time of beginning.	Time of ending.	Total amount of rain.	7 a. m.		2 p. m.		7 p. m.	
				Direction from.	Miles per hour.	Direction from.	Miles per hour.	Direction from.	Miles per hour.
Aug. 12.....						SE....	7	SE....	15
Aug. 13.....				Calm...	0			SE....	7
Aug. 14.....				do.....	0			SE....	7
Aug. 15.....				SW....	3	S.....		SE....	8
Aug. 16.....	3:15 p. m..	3:25 p. m..	Inappreciable...	Calm...	0	SE....	12	SE....	5
Aug. 17* {	3:35 } p. m.	4:40.....	do.....	E.....	2	SE....	14	SW...	5
	8:30 }	Dur. night	do.....						
Aug. 18. {	10:30 a. m.	10:32 a. m.	Sprinkle.....	SE.....	4	S.....	13	SE....	7
	11:15 a. m.	11:17 a. m.	do.....						
	4:50 p. m.	5:30 p. m.	0.02 inch.....						
Aug. 19.....				S.....	10	SW...	7	S.....	
Aug. 20†.....	4:58 p. m..	9:00 p. m..	Inappreciable...	S.....	12	S.....	5	SW...	18
Aug. 21.....				Calm...	0	SE....	3	S.....	3
Aug. 22.....	7:40 a. m..	About 11 a. m.	Inappreciable; fine mist.	NE.....	17	NE....	11		
Aug. 23.....						S.....	5	SE....	6
Aug. 24.....				S.....	8	SW...	22		

* At intervals.

† Sprinkle at intervals.

Report of tri-daily observation made August 12 to 24, 1891, at the "C" ranch, 16 miles north and 12 miles west of Midland, county of Andrews, State of Texas—Continued.

Date.	Aneroid barometer.			Total wind movement in miles.		
	Central time.			Central time.		
	7 a. m.	2 p. m.	7 p. m.	7 a. m.	2 p. m.	7 p. m.
August 12		27.184	27.152	-----	-----	60
August 13	27.201	*27.180	27.090	48	-----	†51
August 14	27.165	27.090	27.032	54	-----	†71
August 15	27.117	27.065	27.022	58	54	40
August 16	27.153	27.100	27.050	98	37	75
August 17	*27.130	27.100	27.030	56	76	68
August 18	27.110	27.045	27.030	59	74	73
August 19	27.060	26.985	26.912	55	81	53
August 20	27.021	26.948	26.970	98	82	57
August 21	27.030	26.952	26.887	61	50	40
August 22	27.177	27.250	27.23	130	84	-----
August 23	27.320	27.230	27.12	-----	†111	29
August 24	27.102	26.98	-----	92	117	-----

* From barograph curve.

† For 12 hours.

‡ For 19 hours.

GEO. E. CURTIS,
Meteorologist.

Observations were also made by myself at other times than those given in the above table, and it is to be noted that observations taken from the anemometer at regular intervals only would not give a correct idea of the windy nature of the region and the wind velocity, since the wind generally blows in gusts. It is very seldom calm, excepting in the night and early in the morning. The prevailing winds are southerly.

There was no firing whatever on the 10th and 11th, and though the map of the Weather Bureau of 8 p. m., August 11, shows a rainfall at Abilene of 2 inches, the rain being of very great extent also, there was no rain at the "C" ranch subsequent to the rain of the 10th, nor did it rain there on the 12th, 13th, 14th, or 15th.

During the 11th, 12th, 13th, 14th and 15th, work was done in getting the apparatus and material into place and condition. Strenuous efforts were made to get the oxygen and hydrogen generators into proper operation. The oxygen apparatus was found to be defective especially when exposed to the high winds, and great delay resulted also from the necessity of putting together and setting up the large hydrogen-generating tanks and waiting for them to soak and become gas-tight. Balloons were partly filled, but were damaged. Kites were sent up on the middle line; but, owing to the character of the wind, they were soon broken in body or broke their strings and were blown miles away.

In the afternoon of August 12, at about 5 o'clock, a few kites were got up close to the house, each carrying a one-half pound stick of dynamite. The air was so nearly calm that a kite could be kept up only a few minutes. Each kite was held by a cord from its body connecting with a two-conductor insulated wire passing to the electrical discharger on the ground, and the dynamite stick was suspended about 20 feet from the kite by the wires of an electric fuse, the lower end of the wire being wrapped about the stick to sustain it with the cap inserted into the stick, and the upper ends of the wires connected with free clean ends of the two-conductor wire. At about 5:45, the wind blew up suddenly very strong from the southeast, bringing clouds which were very dense over the southern sky. The velocity of the wind was 30 miles an hour. There was no rainfall.

On the 13th, Dr. Rosell, of the Patent Office, and Mr. Keefer, from my office in Washington, arrived. The party was now complete and is shown in the annexed photograph, marked III, as on the porch of the ranch house, Mr. Rannels and the cook being on the extreme left of the party with Mr. Powers next, a herder (behind whom is Mr. Ellis), and Mr. Keefer being on the right, and the rest of the party between; the gentleman dressed in the sash being Mr. Curtis.

There was no firing on the 13th. Time was consumed in attention to the oxygen and hydrogen generators and placing guns. About this time Prof. Longuemare and Capt. Juan Hart came as a committee from El Paso, bringing a letter from the mayor of El Paso, Hon. Richard Caples, to urge me to go to El Paso and operate there.

On the 14th a stick of dynamite was fired close to the house in the afternoon. The 13th and 14th were clear, dry days.

On the 15th, in the evening, a few sticks of dynamite were fired singly, but without apparent effect.

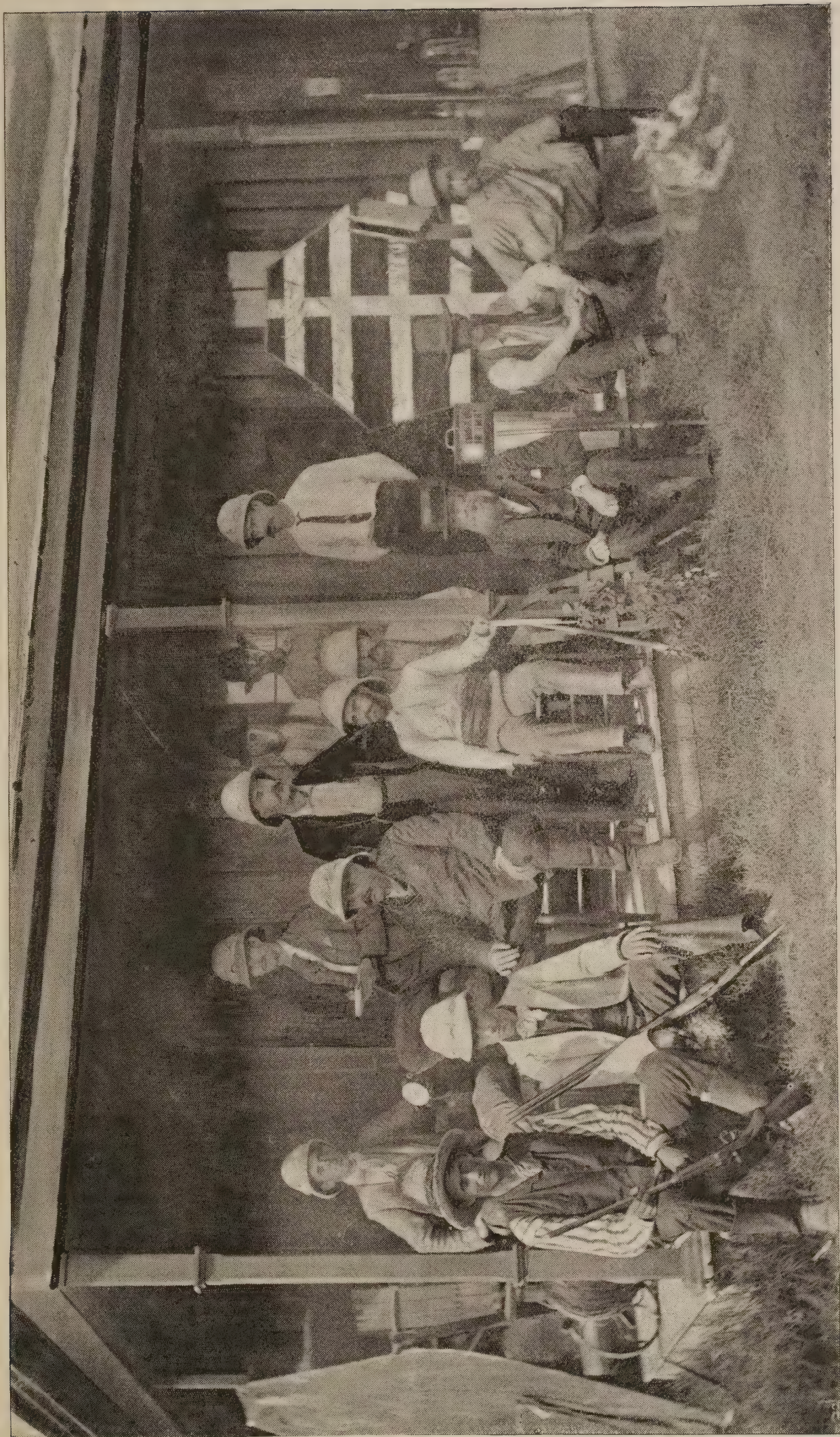
I would say that the firing on the 12th, 13th, 14th, and 15th was on a very small scale (very much less in concussion than that of the 9th), because it was not desired to expend much of any particular explosive until all should be ready for a combined and full operation. What firing was then done was mostly for the purpose of ascertaining how best to explode dynamite in the air, to find out whether, when attached to a kite-connection it would break that connection, and to learn how far it should be from the kite.

The morning of the 16th was calm, and, with one of the herders, I went on horseback to the southwest of the house, to the front line, and, carrying a quantity of blasting powder and dynamite and rackarock, we loaded some of the guns to learn how best to fire them. We also experimented in firing dynamite and rackarock, that I might learn whether it was best, so far as concussive effect is concerned, to put it into the ground or to fire it above ground. We fired the guns planted in the ground, as already described, and loaded with the blasting powder. The concussive effect upon the air was slight, but considerable smoke was produced. We next loaded with rackarock. The concussive effect on the air upon discharge was greater than from the blasting powder, but was not very great. The gun, however, was destroyed. The piece of wrought-iron pipe constituting it was fimbriated about half its length.

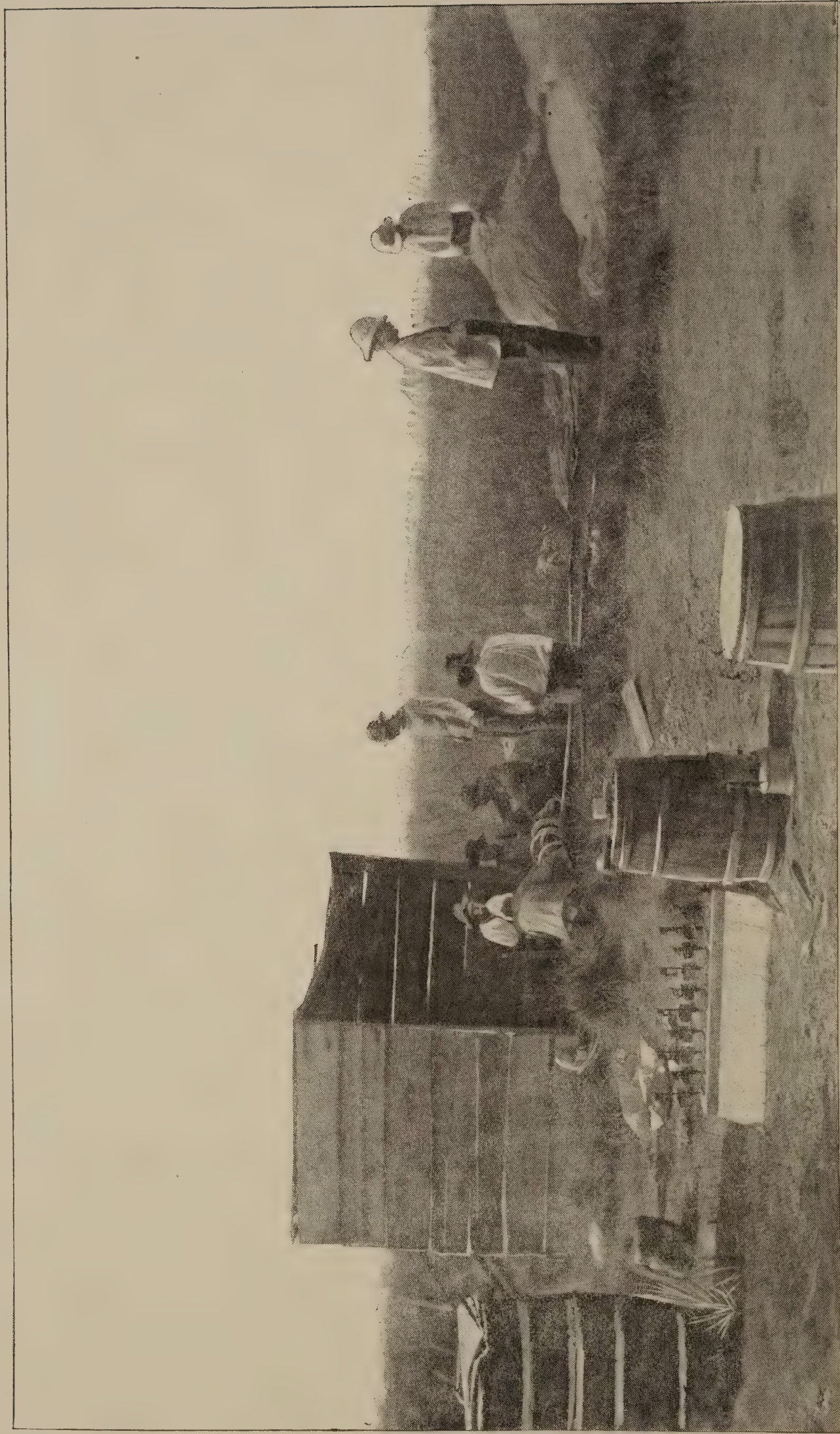
We next fired dynamite and rackarock blasts in dog holes. The tearing up and shaking of the ground was great and astonishing, but the concussive effect upon the air was not great. There was not much noise from the explosions. We next exploded charges of dynamite on large flat stones on the ground. The stones were broken and the concussive effect on the air was strong. We next exploded charges of rackarock on large flat stones on the ground. The concussive effect on the air was greater. These experiments determined me to produce all explosions thereafter, excepting where I had my guns and mines, above the surface of the ground.

Starting to return to the house at about 10 o'clock I noticed that cumulus clouds, which heretofore had never made their appearance before half past 11 or 12 o'clock in the morning, were already thick in the southeast whence the wind now began to blow, moderately at first, but soon increasing to a stiff breeze. Soon after noon the sky was nearly covered with large round and darkened cumulus clouds.

Great delay had resulted from the necessity of putting together the large hydrogen tanks and it was then necessary to wait for them to



III. The party.



IV. Shelter for oxygen apparatus, with party at work.

soak and become tight. No experiment would have been made until everything was ready for a full test but that a number of interested persons had come to the ranch, some of them from a considerable distance, to witness the experiments, and I desired, if possible, to show them something of the process and methods of operation; therefore, early in the afternoon of August 16, the inflation of a 10-foot balloon was begun.

The cloudiness continued to increase and the filling of the balloon proceeded slowly, owing to the defects in the oxygen-generating apparatus and for want of a suitable shelter. A rude shelter was afterward constructed, as shown in the annexed photograph marked IV.

I directed Dr. Rosell to begin preparation of ground explosions of rackarock, in order to experiment under these conditions. The rackarock was tied in bundles of from five to twelve cartridges, with an electrical fuse in the middle. These bundles were suspended 3 or 4 feet from the ground, on mesquite or other bushes, and were exploded from time to time from one of the dynamos or electrical dischargers. At 3:15 p. m. rain began to fall from these cumulus clouds overhead for about five minutes. The amount of rainfall was reported to me as inappreciable. About 50 pounds of rackarock were exploded. About fifteen minutes after 6 p. m., the balloon having been filled, a blasting fuse, to burn about three minutes (much too long a fuse), was inserted, and, after about half an hour's delay, and some difficulty in moving the balloon a short distance from the spot where it was filled, owing to the fact that the wind was buffeting it about, blowing at about the rate of 15 miles an hour, the fuse was lighted by Dr. Rosell and the balloon was set free. It rose rapidly, but passed with great apparent speed to the northwest. At the height of a little over half a mile it moved to the eastward, and there, at the height of about a mile, began moving south, when, at a distance of about 2 miles from the place where it was let go, and at the height of a little over a mile, it exploded. I believe that the balloon when it exploded was a little over 2 miles from the ranch house. These distances are estimated, but were estimated by the balloonist with the eye of an experienced aëronaut. It was noticeable that after the balloon had risen to the height of about half a mile its lateral movement was much less rapid. Owing to the strong wind which was blowing from our direction toward the balloon when it exploded and the distance at which it exploded, the sound was quite faint. It was the intention to ascertain the distance of the balloon, when it should explode, from the place whence it started by observation of the flash and counting the seconds from the time of the flash to the report of the explosion, but from an oversight this was not done.

The explosion of the balloon was not accompanied by any precipitation, nor was there rainfall immediately thereafter. At 8 o'clock, however, heavy rain clouds were seen to form in the west-southwest and rain fell from them heavily, accompanied by lightning. These rain clouds appeared as an isolated mass, and the precipitation seemed to dissipate them. There was no rain at the ranch house. Late that night the wind backed to the east and blew a gale.

The maps of the Weather Bureau of the 14th, 15th, 16th, and 17th and the map of 8 a. m. of the 18th show no rain nor indications of rain during this period up to 8 p. m. of August 18.

On the morning of the 17th there was dew on the grass for the first time. About 10 o'clock on this morning, the wind being east, the ground batteries having been connected by wires to the electrical dischargers, heavy explosions were made at frequent intervals and some

of the blasts were fired. Mr. Ellis, Dr. Rosell, Mr. Draper, and Mr. Keefer tied rackarock cartridges into bundles about a central stick of dynamite containing the cap, hung them as high as possible upon the bushes, and discharged them with very powerful concussive effect.

At this point I would mention a peculiarity of rackarock as compared with dynamite. If two dynamite sticks were laid upon the ground, say 18 inches apart, and one stick was fired by an electrical fuse-cap, the other stick would always explode also; whereas, if two rackarock cartridges were laid at the same distance apart and only one was fired, the other would not explode. The rackarock cartridges might even be placed within 6 inches of one another without the firing of the one exploding the other.

I am informed that it has been stated that the first explosion on this day took place in the evening. I can only say that the statement is erroneous.

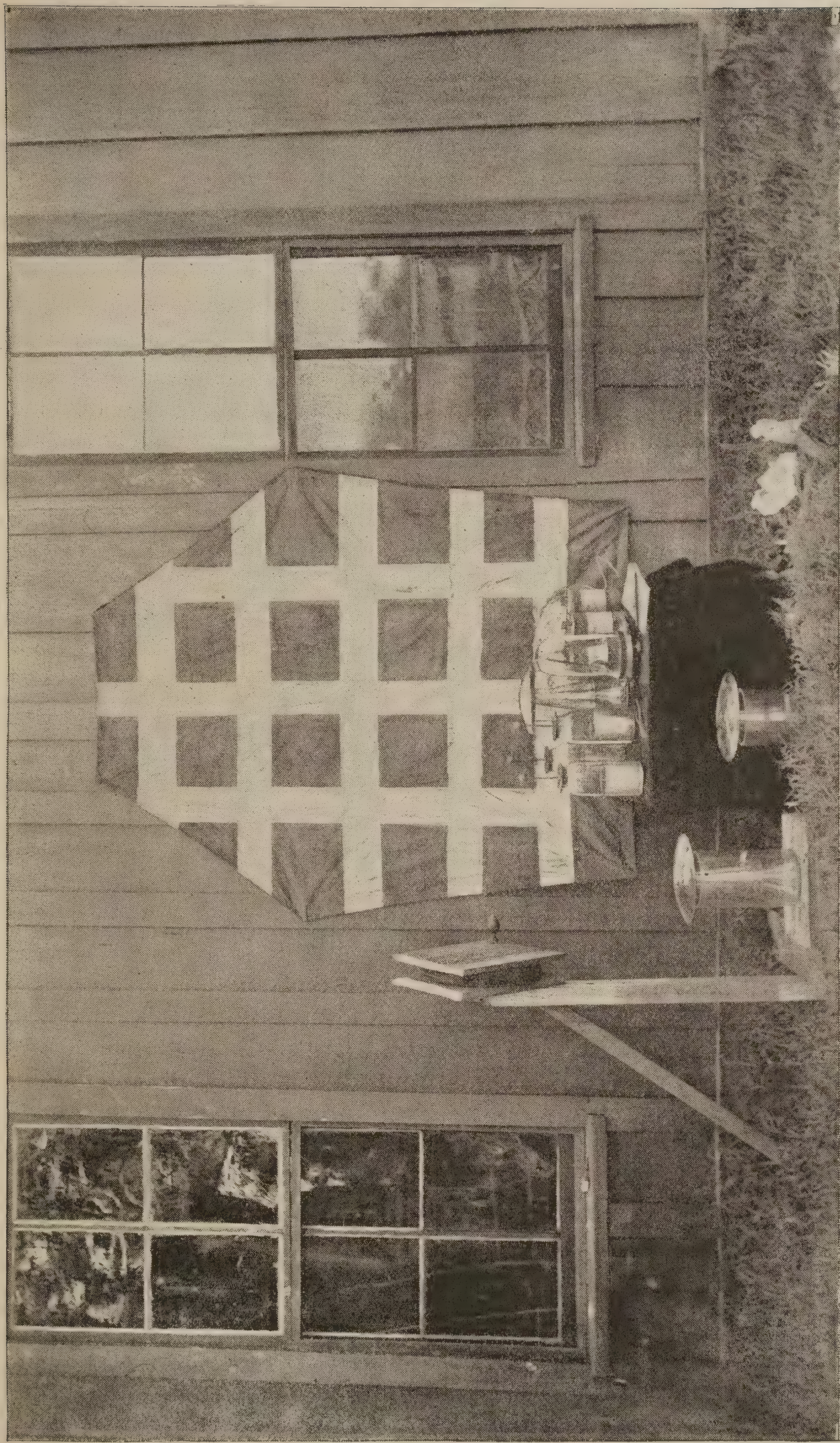
The morning was very clear, except that cumulus clouds had begun to form at 10 o'clock in the forenoon, about two hours earlier than usual. Early in the afternoon the sky was almost covered with cumulus clouds, and there was a strong wind of about 15 miles an hour from the east and southeast. Between 3 and 4 o'clock in the afternoon, heavy storm-clouds were visible in the west. The firing continued and the wind was southeast. The storm went around to the south and heavy rain could be seen in the south pastures of the ranch, which covered an area of about 500 square miles, and some of the men who were engaged in the explosions, at a point about a mile south of the ranch-house, were soon driven into the house by rain. The rain was accompanied by thunder and lightning, but was much heavier to the south and southwest than at the ranch-house, extending to Midland. In going to Midland from the ranch-house on the 18th, from about 2 miles from headquarters to Midland, the roads were heavy with mud. The heavy rain-clouds did not seem to come directly before the wind, but seemed to be whirled by eddies toward the zenith. The rain extended to the ranch-house, where it began to fall about half-past 4. The rain at the ranch-house, however, was light, so that it was reported to me as not measurable. In the south and southwest, however, the rain could be seen falling in torrents. At the ranch-house itself the appearance of storm was very strong, and heavy storm-clouds extended to the northwest far beyond the ranch-house, where rain was also seen to fall in torrents.

Between 4 and 5 o'clock one of the electrical kites was sent up, and managed by Mr. Draper. The kite soon became highly charged with electricity and, being connected with one of the sulphuric-acid condensers, a spark of over half an inch was obtained.

The form of kite employed, being one supplied with bands of tin-foil, is shown in the annexed photograph, marked V, where also appears other electrical apparatus used by the expedition.

I would state here that it was my intention to send up an electrical kite at the same time as and in proper juxtaposition with balloons, the object being to ascertain, if possible, what might be the static electrical condition of the atmosphere previous to an explosion; then to recognize what, if any, electrical effect may accompany an explosion, and, finally, whether any electrical effect succeeded the explosion as the result thereof; but partly owing to the great difficulties with which I had to contend from the high and irregular winds and partly from other unforeseen causes, I was not able to do anything of importance in this respect. I suggest trials in this line.

Between the night of the 16th and the evening of the 17th there were



V. An electrical kite.

exploded about 200 pounds of dynamite and rackarock and 525 cubic feet of oxy-hydrogen gas. Between 5 and 6 o'clock in the evening some more rackarock was fired, the wind being then strong from the southeast, but the firing was not followed by rainfall at the house. The storm seemed to have passed over to the northwest, where it was very dark and where rain was seen to fall. Soon after the firing the wind went around completely, and between 6 and 7 o'clock thunder-heads and lightning were seen in the southeast, and the storm from here backed to the north. Before 8 o'clock lightning was seen in the northeast as well as in the southeast, the entire sky overhead became darkened with storm-clouds, and the wind changed to the south-southeast. Preparations were then made to fire some dynamite. At half past 8 a number of sticks were fastened together and exploded. Directly thereupon there was a light dash of rain from the clouds immediately overhead, but it lasted only a few moments. Explosions of rackarock were also made at intervals during the evening, and the sky being heavy with clouds, each explosion was followed by a spatter or flurry of rain. Between 10 and 11 o'clock a light drizzling rain set in, and it was drizzling when I retired, about 12 o'clock; but the next morning I was informed, to my surprise, that the rain-gauge showed no measurable quantity.

On the morning of the 18th the sky was completely covered with stratus clouds, and between 10 and 11, and 11 and 12 there were sprinkles of rain. In the afternoon, between 2 and 3 o'clock, there was a strong wind of about 13 miles per hour from the south and a heavy storm was seen in the east, where thunder was heard soon after 3 o'clock in the afternoon. I then directed the firing of rackarock and the explosions began about 4 o'clock and were kept up at intervals. In all, about 90 pounds were exploded in sixteen blasts. When the firing began the wind was blowing from the east at the rate of 20 miles per hour. In about three-quarters of an hour from the first explosion it began to rain and the rain continued about an hour. I was informed that the rain gauge showed a rainfall of 0.02 of an inch. Rain was seen to be falling heavily in the east, but no more rain fell at the house that evening. After about half past 5 there was no more firing.

The maps of the Weather Bureau of August 17, 8 p. m., and 18, 8 a. m., give no forecast of this storm, but the rain is shown on the map of August 18, 8 p. m.

From the beginning of the firing on the 16th up to and including the night of the 18th, there had been an apparent disturbed condition of the atmosphere with hauling and backing winds and wandering storms. These are conditions which I am informed by residents of this region had never been observed there before and created surprise.

The morning of the 19th was clear and the day remained so. There was no firing, and some of the members of the party, with the assistance of some mechanics of the ranch, were engaged in repairing the oxygen apparatus.

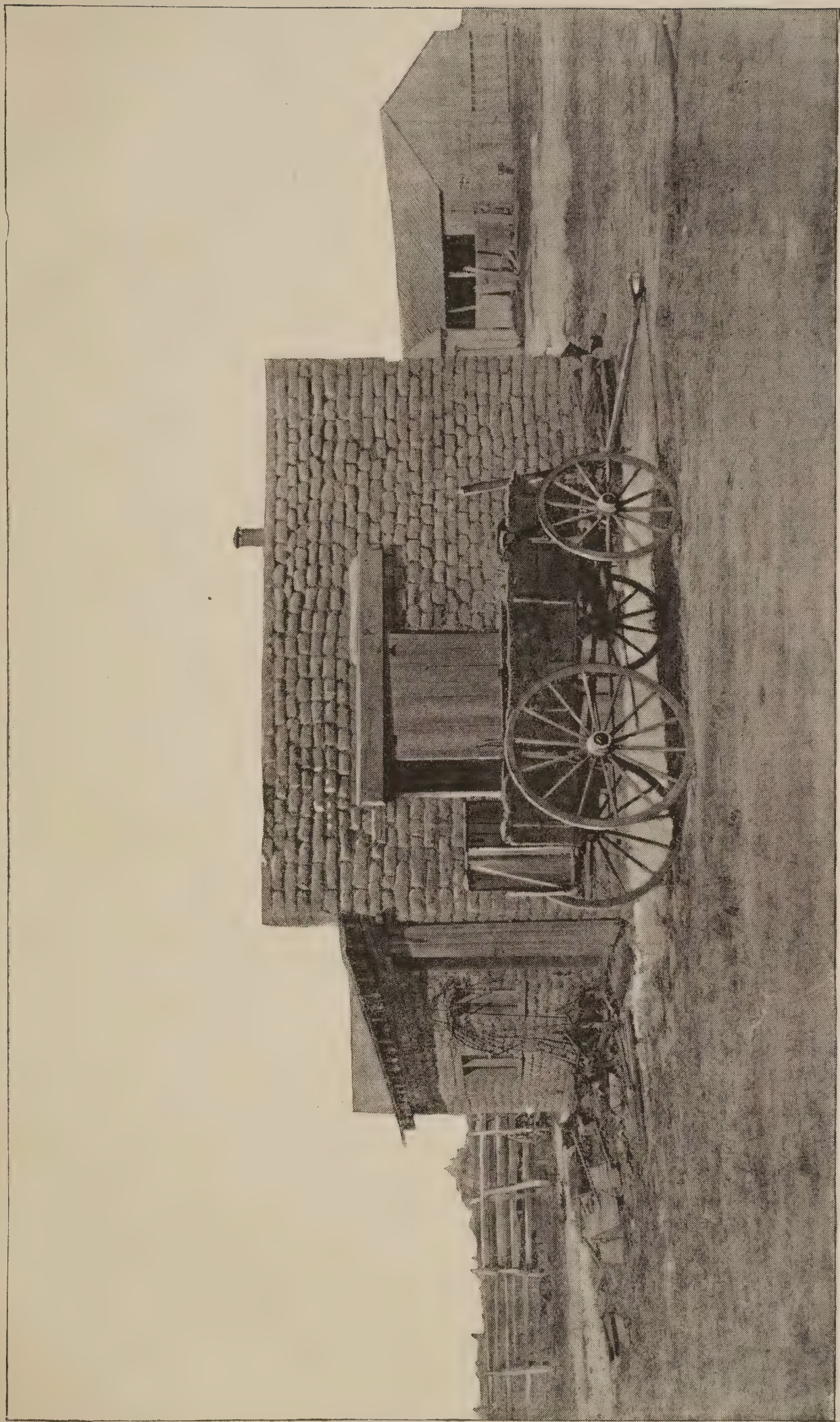
Dr. Rosell, Mr. Casler, Mr. Draper, and Mr. Keefer were sick and obliged to be in bed from the effects of the alkaline water, which produced severe pain in the back across the kidneys, accompanied by high fever. Every one of the party, with the exception of myself, was ill from this cause and had been so at different times before this. From service in the Army, on the plains, heretofore, in alkali regions, I had learned to beware of the pernicious water, and I warned my assistants, but the climate being very hot and being often exhausted and thirsty from hard work, they were heedless until after they had suffered. I

recommended treatment of the water with sulphuric acid and this was beneficial.

In order to repair the apparatus it was brought up from the east mill to an adobe building, a blacksmith and machine shop, near the ranch house, shown in the annexed photograph marked VI.

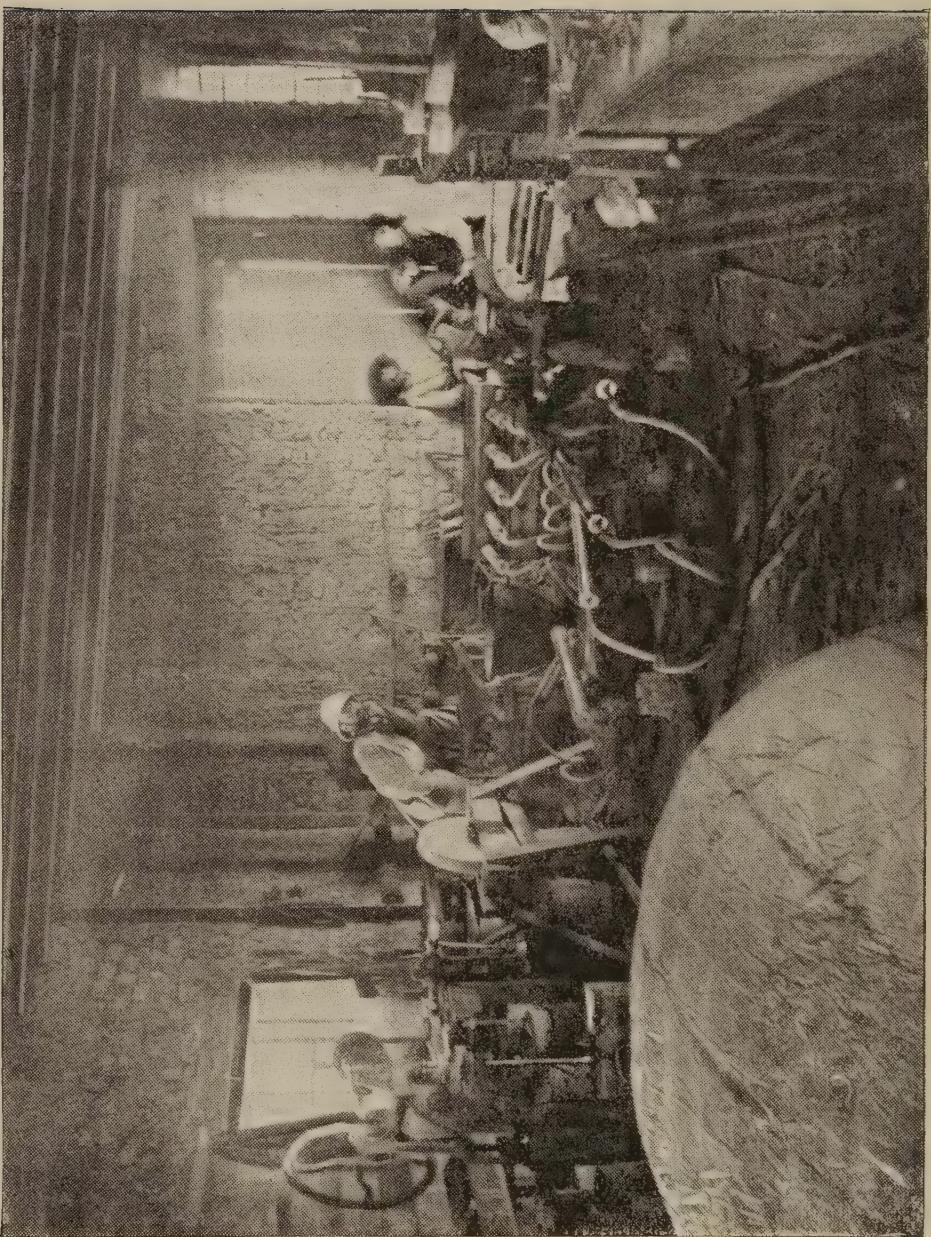
On the morning of August 20, the sky was clear and there was a strong steady wind of about 12 miles an hour from the south, which at about 11 o'clock, backed to the southeast. Desiring to find again the place of every gun and mine on the front line, as little flags which I had placed one at each spot where a gun or mine was located had been blown away, I started out about 10 o'clock on horseback with a herder named Kelly, who had had some experience in blasting, to the west-southwest of the ranch, to begin with the first gun and mine at that end. We carried with us an electrical discharger and about fifty rackarock cartridges and a few sticks of dynamite. We found that the first gun was already loaded with blasting powder. We pulled it almost entirely out of its excavation, saving as much of the powder as we could, and re-inserted it to the depth of only a few inches, and re-loaded it with the powder and two inserted cartridges of rackarock. The charge was exploded from the electrical discharger, the cap being inserted between the cartridges. Most of the powder was ignited. The concussion was strong, but not so great as when rackarock is fired unconfined. The tube, constituting the gun, was broken into many pieces. We then moved to the south along the line, firing some blasts and some dynamite and rackarock. Somewhat later, some of the party, I think Mr. Draper and Mr. Keefer, came out and we hung bundles of eight, ten, and sixteen sticks of rackarock with a stick of dynamite inside, on the bushes and exploded them one after another. On the explosion of the last charge, the largest one, I noticed a peculiar rising of the top portion of the smoke in faint ring form with a lateral whirling motion from right to left, the ring widening as it ascended and disappearing. And the smoke on the ground and the ring moved with the wind. The rising of the ring seemed to be accompanied by a peculiar sound, distinct from the noise of the wind. The sound was so uncertain and lasted so short a time that it did not make a strong impression upon me at the time, and I forgot about it until I was informed by Mr. Ellis and Lieut. Dyer, that, in subsequent experiments, they had sometimes noticed the same thing. The wind had backed somewhat farther to the east, but directly after the last explosion, it hauled back to the south. I then rode around the entire line and returned to the ranch house by way of the east mill.

After noon the wind abated considerably, but heavy storm clouds began to make their appearance in the northwest, extending to the north, and by a few minutes after 4 o'clock they had risen to the middle of the sky. At about half past 4 the wind shifted to the north and blew over 20 miles an hour. I then directed the firing of some rackarock, and a charge of six cartridges was exploded at about 5 o'clock. A few minutes before the explosion, however, there was a slight sprinkle of rain. A charge of ten cartridges of rackarock was then exploded, about five minutes after the first, and a charge of twelve cartridges was exploded about ten minutes later. The charges were not followed by any immediate rainfall at the ranch house, but Dr. Rosell, who had done the firing at about half a mile to the south-southeast of the house, and others who were with him, told me that directly after each explosion they had felt the rain spatter in their faces for a few moments. At about half past 5 there was a light rain at the ranch house. The storm was passing rapidly to the southwest, and at about a quarter to 6 a



VI. The adobe blacksmith and machine shop.





VII. Interior of adobe, with oxygen apparatus.

fourth charge was exploded, and again the party felt a spatter of rain. A heavy storm, with thunder, was seen in the southwest. The sky continued very heavy. About 6 o'clock a kite was sent up carrying two sticks of dynamite, but just before the dynamite was exploded it began to rain, and the rain continued for a few minutes only. At about half past 6 the wind shifted to the southwest and the sky was clearing in the northwest and north. There were still storm clouds overhead, however, and at about 7 o'clock I directed the explosion of four sticks of dynamite on a bush. The explosion was followed immediately by a light rain, which lasted, from a sprinkle to a light shower, for about fifteen minutes, and light sprinkles continued during the evening. A heavy storm, accompanied by lightning, was observed in the south during the rest of the evening.

On the 21st, work progressed on the oxygen apparatus, though the day was so very hot that it was not possible to do much work. After sundown, and up to 9 o'clock, about 160 pounds of rackarock were exploded in fifteen charges. The wind was south. At about 12 in the night the wind shifted to the north, and it blew up very cold in strong gusts.

The morning of August 22, was foggy and the sky was entirely overcast. The wind was blowing in strong gusts from the north, and it was so cold that fires were built. Beginning at about half-past 8, and at short intervals, seventeen charges of rackarock were exploded in bundles of from six to twenty-five cartridges each. The explosions were seen to condense and dissipate the mist for a few moments where they occurred. The mist continued until about half-past 10 a. m. There was no rain. The Weather Bureau map of 8 p. m., August 21, predicts a cooler temperature for the 22d, with showers in the northern part of Texas, and the Weather Bureau maps of August 22 show a rain extending from far eastward to and beyond Abilene.

On the afternoon of August 22, by reason of the expiration of his leave, Dr. Rosell was obliged to leave the party and return to Washington, and he went, accompanied by Mr. Keefer.

On the morning of August 23 there was a heavy dew by the cooling of the ground. The day was clear.

Having become convinced of the inexpediency of the manufacture of oxygen in any situation exposed to the wind, I determined to make a large quantity of oxygen in the adobe hut and store it in one or more of the balloons as reservoirs, and then convey these balloons to the place of operation, charging each balloon thereafter to be filled with the mixed gases, first with the necessary quantity of oxygen from a reservoir balloon and then with the requisite quantity of hydrogen from the hydrogen generators at the place. As hydrogen is more diffusive than oxygen, it is always best to charge the necessary quantity of oxygen first into the balloon to be exploded.

I now renewed every effort to get ready for the grand test, and on the 24th oxygen was made in the adobe and stored in reservoir balloons. The annexed photograph, marked VII, will show the oxygen apparatus and the work in progress.

The 23d and 24th were dry, clear days. The wind was southerly, and on the 24th it blew a gale of about 20 miles an hour from the southwest.

Mr. Curtis's time having expired, he left the ranch to return to Washington.

The map of the Weather Bureau of August 25, 8 a. m., shows a shower at Abilene on the 24th, with wind south; but, as said above, it was dry and clear at the "C" ranch.

THE MIDLAND TEST.

On the morning of August 25 the sky was clear and there seemed to be every indication that the weather was "settled dry," as expressed by the ranchmen. I had hoped for a quiet day, but the wind, which, as usual, had been light during the night, increased soon after sunrise and by 10 o'clock it was blowing from the south at a velocity of nearly 25 miles an hour. The hydrogen-generating apparatus had been started early in the morning and by 10 a. m. several balloons were being rapidly filled. The accompanying photograph, marked VIII, shows the inflation in progress before the wind became strong, the balloon on the ground to the right of the picture being a reservoir balloon containing oxygen.

As the wind increased in strength, the greatest difficulty was experienced in preventing the balloons from breaking away or being destroyed. The work proceeded, however, although in spite of all efforts several balloons were lost at different times during the day, one bursting through its heavy cord netting and others parting the cables by which they were held. The course of each of these balloons, as it rose, indicated that above the strong surface current from the south another current was moving from the southwest to the northeast, at an altitude of about 1 mile, and that above this, at an altitude of 2 miles or more, there was a third current moving from northwest to southeast. At 11 a. m. the first balloon, containing 1,000 feet of oxy-hydrogen gas, was exploded, and during the afternoon three more of the large balloons were exploded.

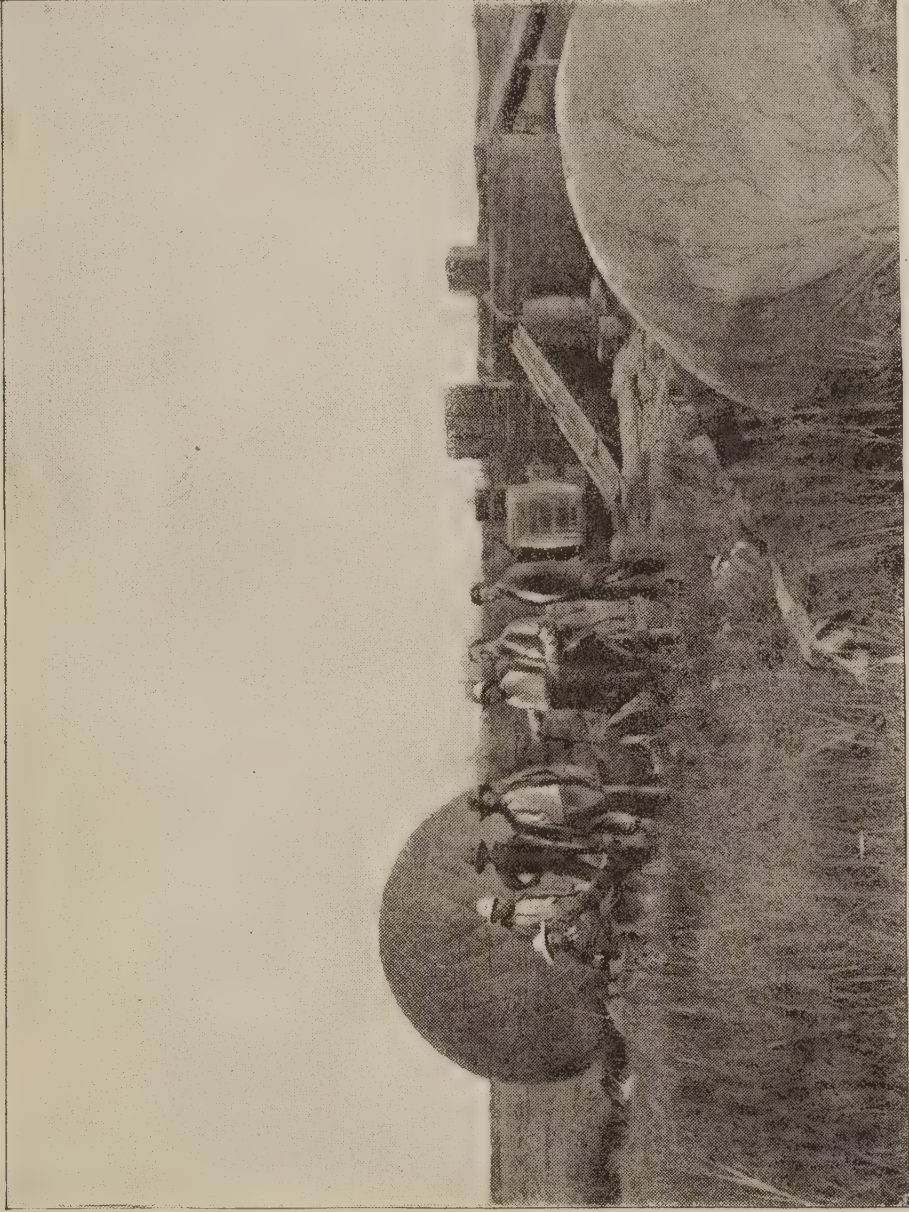
The annexed photograph, marked IX, will show the struggle with one of these balloons.

Most determined and persistent efforts were made to fill a large number of balloons, and carry them out in line, send them up, and explode them; but by 6 o'clock only the few mentioned had been filled and exploded, and the party returned to the house weary and jaded. The balloons which exploded flew directly north. Three balloons were let go free and were fired by short time fuse; but one was held captive and fired from a dynamo or electrical discharger. Owing to the violence of the wind, if the wire, constituting its cable, were merely paid out, the balloon would drag and be beaten down; so, while the balloon was held on the ground, the end of the wire attached to the dynamo or electrical discharger was carried about a thousand feet to leeward, and, the balloon being then liberated, as it passed over and somewhat beyond the spot where the dynamo was, the handle was pushed down and the balloon exploded.

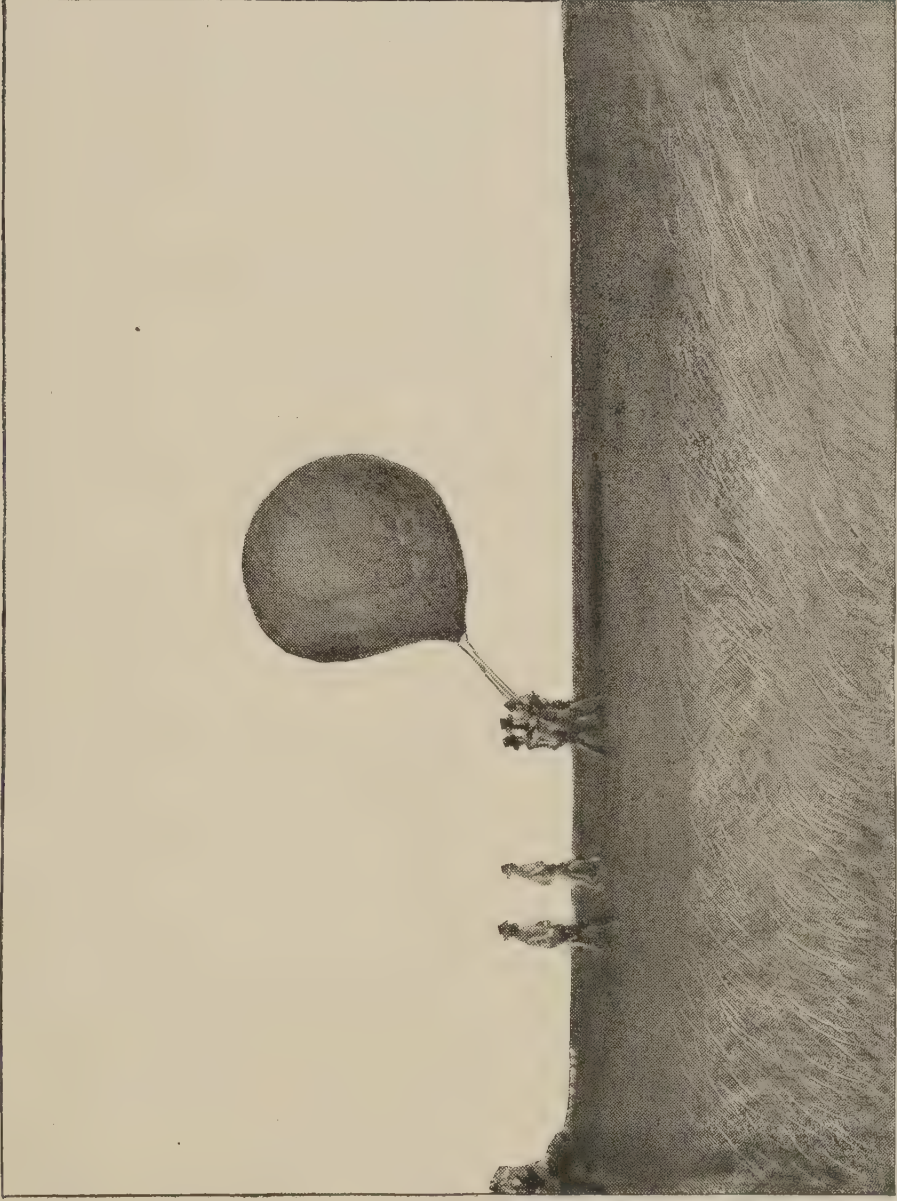
As the last of the free balloons was rising, an interesting circumstance occurred. The balloon had got about three-quarters of a mile from the East mill, when a charge of about a dozen cartridges of rackarock with some sticks of dynamite was fired half a mile directly to windward of the mill.

The wave resulting from the explosion was heard to strike the balloon with such force that the balloon was thought to have been ruptured, and it was seen to careen and sway violently. The balloon was not injured, however and, in about ten seconds, it exploded.

At sundown, ground explosions were begun and they were continued throughout the evening. The charges were very heavy and the explosions occurred at short intervals, 40 pounds of dynamite, 200 pounds of rackarock, 150 pounds of blasting powder being used, and early on the following morning 50 pounds of dynamite and 100 pounds of rackarock were fired in about a dozen heavy charges.



VIII. Inflating the balloons.



IX. A struggle with one of the balloons.

During the day the sky had been very clear, the fragments of cumulo-stratus clouds which appeared during the afternoon (as they do with the utmost regularity on every day during fair weather) being much lighter, higher, and more scattered than usual. At 7.30 a. m. the thermometer had indicated a temperature of 68.4° with the dew-point at 42° , and the relative humidity 37. The barometer had shown a pressure of 29.98 inches with the wind continuing from the southeast at a velocity of 18.16 miles per hour. At 3.30 p. m. the temperature had risen to 92.2° , the dew-point remaining at 42° , and the relative humidity having fallen to 16. Upon the same afternoon, the office of the Weather Bureau at El Paso, 200 miles west, reported the relative humidity at that point to be only 6. This would indicate that upon the day upon which the firing occurred the atmosphere over an extended area was in as dry a condition as it ever is. Such extreme dryness is seldom observed, even in that region. The barometer at this hour indicated 29.93 inches, the wind continuing from the south with a velocity varying from 19 to 23 miles per hour. At this time a few fragments of clouds were floating overhead as usual, but they were at an altitude of 6,000 or 8,000 feet, and very light and scattered.

The firing ceased at about 11 p. m., the atmosphere at that time being very clear, and as dry as I have ever observed it.

At about 3 o'clock on the following morning, August 26, I was awakened by violent thunder, which was accompanied by vivid lightning, and a heavy rainstorm was seen to the north—that is, in the direction toward which the surface wind had steadily blown during the firing, and hence the direction in which the shocks of the explosions were chiefly carried. The storm extended northwest. The wind was directly north, and the clouds approached slowly during the next two hours, until shortly before 6 o'clock a. m. a heavy rain could be seen falling over the north pastures of the ranch. The rain continued falling heavily over the entire north half of the ranch for about two hours. Only the edge of the clouds passed over the ranch-house, however, so that the rain there was slight; but Mr. Rannells, manager of the ranch, an experienced ranchman, and others of the party, and I, estimated the rainfall to be not less than 1 inch and probably as much as an inch and a half on the north pastures less than 2 miles from the house. While the thin edge of the cloud was overhead, a few charges of dynamite were fired near the ranch house. A few moments after the first explosion the first overhead rain began, and after each subsequent explosion rain could be seen falling from the clouds overhead in what appeared to be a heavy shower, but the air was still so dry that at first no rain and afterward only a sprinkle reached the ground. After each explosion the quantity of rainfall increased.

During the forenoon the clouds passed slowly to the east and southeast, and, from reports afterwards received, it was learned that a very heavy rain had fallen over the northern part of the Slaughter ranch, situated east of the "C" ranch, as well as over the rest of the central portions of Andrews and Martin counties, and the storm had then dissolved before reaching points 100 miles east. At Abilene no rain fell, nor did the wind change there, but continued blowing, as upon preceding days, from the southeast. At other Weather Bureau stations, on all sides of us, such as Fort Stanton and Santa Fé, N. Mex., and El Paso and San Antonio, Tex., there was no rain. The storm seems to have been entirely local.

I have seen since that on the map of the Weather Bureau of August

25, 8 p. m., the forecast to 8 p. m. of August 26 predicted local showers on the extreme southeast coast and the northwest (I do not know whether this means the extreme northwest or anywhere north and west of the center of the State); but from what precedes, it appears that while I was in Texas showers were several times predicted for the region and did not occur at Midland and vicinity when there were no explosions, and that when showers were not predicted for the region, and there were explosions, showers occurred; so I do not consider it conclusive that because, in a general way, showers were predicted for the northwest region and we got a rain after firing, consequently, the firing must appear as having been superfluous. Besides what came was not a shower. It was a heavy rain, estimated for the north pastures of the "C" ranch and part of the Slaughter ranch at $1\frac{1}{2}$ inches. The maps of the Weather Bureau of August 26 and 27 show no rain in this region.

At 7:25 a. m., August 26, while there was a sprinkle of rain at the ranch house, and heavy rain was falling to the north and northwest, the temperature was 69.4° , the dew-point 45° , and the relative humidity, 40. The storm clouds extended from a line about 15° above the northwestern, northern, northeastern, and about 20° above the eastern horizon to a little south of the zenith. The barometrical pressure was 30.34 inches, having risen steadily during the preceding 48 hours (.44 inch).

At 3 p. m. the barometer indicated a pressure of 30.06 inches, the temperature was 90.4° , dew-point 45, relative humidity 20, and the wind had hauled to the southeast, and was blowing with a velocity of 17 miles an hour.

After the completion of these experiments and after a thorough test of all the apparatus on hand, I concluded that I might safely comply with urgent requests for my return to Washington, where my presence was imperatively demanded.

On the evening of the 26th I proceeded to Midland, together with Messrs. Powers, Draper, and the balloonist, and on the following morning started for Washington.

During the whole of the time that I was at the "C" ranch, not only was every possible facility extended to the expedition from Mr. Morris, to whom I desire to express my thanks, but cheerful and most efficient assistance was rendered by the personal attention of Mr. E. W. Rannels, the manager of the ranch, to whose untiring zeal and courtesy every member of the expedition testifies, and to whom whatever success was achieved, is, in a great measure, due.

I left Mr. Ellis and Mr. Casler at the "C" ranch in charge of the apparatus of the expedition, with instructions to remain at that point a few days, in the hope of securing a calm day on which to make another experiment, and then to transport the apparatus to Midland Station and ship it by freight to El Paso, where, upon the invitation of the mayor and prominent citizens, I agreed to make a test, provided the local expenses of teams, labor, and hotel bills should be paid and transportation to and from that point be furnished, saving that amount to the appropriation.

Being unable to return to Texas during the next few weeks I found it necessary to leave the immediate conduct of the subsequent experiments to Mr. Ellis, to whom I gave careful instructions and whom I knew to be competent to prosecute the investigations in the best possible manner.

I kept in constant communication with him by mail and telegraph. Mr. Ellis carefully followed all instructions given him, and his management and the subsequent work of the expedition have been satisfactory.

Upon your request, at my suggestion, Lieut. S. Allen Dyer, of the Twenty-third Infantry, U. S. Army, who gave valuable assistance and worked with Mr. Ellis during the experiments at El Paso and San Diego, has been detailed by the Secretary of War to assist Mr. Ellis in making his report.

Concerning the subsequent movements of the party in the experiments at El Paso and San Diego, I respectfully invite your attention to the following reports of Mr. Ellis and Lieut. Dyer, together with attached statements, letters, and meteorological data.

REPORT OF MR. ELLIS.

WASHINGTON, D. C., *December 1, 1891.*

R. G. DYRENFORTH,
Special Agent, Department of Agriculture:

SIR: The departure from Midland of Dr. Rosell and Mr. Keefer on August 22, of Mr. Curtis on the 24th, and of yourself, with Messrs. Powers, Myers, and Draper, on the 27th, left Mr. George E. Casler and myself in charge of the apparatus and unused material of the expedition at the "C" ranch.

In accordance with your instructions, I secured the services of Mr. N. A. Jennings, who had come from Dallas, Tex., to witness the experiments, and had rendered valuable assistance in the work of the 25th of August, to assist Mr. Casler and myself in the work before us.

Your instructions to me were, to remain at the "C" ranch a week or ten days in the hope of securing a moderately quiet day in which to make another test, and then to transport the outfit of the expedition overland by team to Midland, and thence, by the Texas and Pacific Railway freight, to El Paso, and prepare for the test at that point. During the next week the wind did not moderate, but attained a velocity daily of from 15 to 26 miles an hour.

On the 31st of August, in company with Mr. Jennings, I drove to Midland, where I received a message from Mayor Caples, of El Paso, under date of August 27, as follows: "Have made all arrangements you requested in letter of 24th instant. When can we expect you?" I telegraphed in reply that we would ship the apparatus during the week, and that another week at least would be required in which to set it up.

In the letter file which you left with me, I discovered a circular from the New York Oxygen Company, stating that they were prepared to furnish pure oxygen gas, stored in seamless steel cylinders, under a pressure of 120 atmospheres. I estimated that by this means we could procure our oxygen gas at great economy of both time and money over the method we then employed. I therefore telegraphed the New York Oxygen Company on September 1, to furnish me prices and information concerning weight of cylinders, etc., and on September 2, I received the following reply by telegraph:

"Oxygen, 5 cents per cubic foot, cash, f. o. b. New York, subject to satisfactory guaranty for prompt return of cylinders here, free of expense to us. Weight of cylinders charged, 95 pounds each.

LENOX SMITH, *President.*"

Upon the same day I received the following reply to a message, sent September 1, to the Consolidated Fireworks Company of North America, in New York City:

"Bomb-shell salutes, 21-pounders, \$17 per dozen, net. These are heaviest reports made. We mail catalogue.

CONSOLIDATED FIREWORKS OF AMERICA."

For use at El Paso, in addition to materials we had on hand, I desired to procure materials, necessitating an expense as follows, viz:

2,000 cubic feet of oxygen, at 5 cents per cubic foot	\$100
6 dozen bomb shells, at \$17 per dozen	102
500 pounds of dynamite, at 15 cents per pound	75
Express from New York on oxygen and bombs, about 20 cwt., at \$10 per cwt	200
Total	\$477

On account of the smallness of our party it would be very difficult to manufacture our own oxygen at El Paso and carry on the other labors of an experiment at the same time. It therefore seemed important that these materials should all be secured in time for the test. However, the Government appropriation could not spare the necessary funds. The people of El Paso had only agreed to furnish transportation and pay local expenses of labor, teams, and hotel bills. I decided to ask them to assume these additional expenses and took the night train for El Paso, Mr. Jennings returning meanwhile to the "C" ranch.

I arrived at El Paso on the 3d and received a warm welcome at the hands of Mayor Caples, Capt. Juan S. Hart, of the El Paso Daily Times; Prof. Longuemare, of the Bullion, and Mr. Kelly, of the city council. I laid the proposition before the gentlemen, who gave most considerate attention, and was then driven to the "mesa" or table-land back of the city, to select a place for operating. The spot which seemed most suitable for the balloon apparatus was a ravine or "arroyo," about $1\frac{1}{2}$ miles north of the center of the city, at the foot of one of the walls of the City Water Company's reservoirs. In this hollow the balloons while filling would be protected from the wind, which prevails from the southeast at an average velocity of about 10 miles per hour, and an abundant supply of water for the hydrogen generator could be obtained through hose laid from the reservoir.

I also called at the office of the Weather Bureau and had a conversation with Mr. Love, the observer at that point.

That evening the city council at a special session agreed to pay the expenses of procuring the oxygen, bombs, and dynamite, and authorized Mayor Caples to make any other expenditures he deemed advisable. The bombs and oxygen were immediately ordered by wire to be shipped by express.

On the 4th of September I returned to Midland, where I was met by Mr. Jennings. On our return to the ranch we found that the ranch "outfit" had gone to Colorado City to ship cattle, leaving only the cook and two or three men who were on the sick list and could give us no assistance.

It was impossible to get the assistance of any of the freighters or other laborers of Midland on account of their fear of our explosives and electrical apparatus. Mr. Casler, Mr. Jennings, and I, therefore, packed our paraphernalia in the wagons as rapidly as we were able and hauled it ourselves with mule teams to the railroad at Midland. Mr. Casler, being too ill to drive a team, was brought in the next day in a carriage.

The material brought from the ranch was as follows: Two hydrogen-generating tanks, with wash barrels, etc.; 1,900 pounds chlorate of potash, in kegs; 500 pounds binocide of manganese; 500 pounds of rackarock; 2,000 pounds of sulphuric acid, in drums; 1,000 pounds iron borings; thirty-three 10 and 12 foot balloons; one 20-foot balloon for explosive purposes; one 22-foot balloon for ascensions; 7 dynamo dischargers; 12 boxes and trunks, containing fittings and instruments; 2,000 pounds oxygen furnaces, cylinders, and wire. This material we loaded into a freight car, together with 12,000 pounds of sulphuric acid, 5,000 pounds iron borings, which had been stored at the Midland freight depot, and shipped it to El Paso.

Foreman Jesse Corne and the ranch "outfit" returned before we had finished loading and gave every assistance possible. Mr. Casler and I left Midland on the evening of Wednesday, September 9, and reached El Paso at noon the following day. El Paso is situated in the midst of an exceedingly dry and barren region in the fertile valley of the Rio Grande, 840 miles from the Gulf of Mexico. Mr. Jennings remained at Midland to bring in another load of our apparatus and start the car, following us to El Paso September 12. On the 13th we were joined by Mr. Eugene Fairchild, whom I had called, in accordance with your instructions, from Oberlin College, Ohio, to assist in the chemical and electrical work of the operations. The carload of apparatus and chemicals also arrived from Midland on the 13th.

Soon after our arrival at El Paso, Maj. James Henton, commanding officer of Fort Bliss, El Paso, called on me at the hotel and very kindly offered any assistance he might be able to furnish in the shape of men and teams. The major also handed me a letter from the San Antonio Board of Trade and Gen. D. S. Stanley, commanding the Division of Texas, U. S. Army, urging that we come to San Antonio to make further experiments, and proffering all the assistance they might be able to give. In reply, I informed the Board of Trade and Gen. Stanley of the arrangements which you had already ordered for experiments at El Paso and in Southern Texas, and, after communicating with you, stated that I knew of no reason why we could not come to San Antonio immediately after finishing the work at these points.

On Monday, Tuesday, and Wednesday, the 14th to 16th of September, the apparatus and materials necessary for the experiment were hauled to the point selected upon the "mesa" back of the city, beside the water-works reservoirs. Here the hydrogen generator was set up in the sheltered ravine. Fire hose was laid from the reservoir. A hut, 12 by 14 feet in dimensions, was erected, in which the balloons, dynamos, instruments, and fittings were stored, and 3,000 pounds of iron and 3,600 pounds of sulphuric acid were brought from the car for use in making hydrogen gas. On the 16th, burros were loaded with 400 pounds of dynamite, 100 pounds of rackarock, 20 bombshells, 2 mortars, 2 dynamos, wire, exploders, etc., and proceeded to the summit of the southern end of Mount Franklin, a point 3 miles east of the balloon apparatus, with an altitude of about 2,000 feet above the Rio Grande at El Paso and 5,700 feet above the sea level. Mr. Jennings was given charge of the preparations and execution of this part of the work.

The following day, Thursday, the 17th, the 22 feet (diameter) balloon was inflated with hydrogen for use by me in making an observational ascension, to get some data concerning the temperature and humidity of the various currents and strata of the upper air.

I carried a barometer graduated to read hundredths of feet, a "wet and dry bulb" thermometer, or psychrometer, for determining the humidity of the air, and a photograph camera. The balloon was heavily ballasted with sand bags so that the ascension might be gradual, giving time for making careful readings of the instruments at short intervals.

The balloon was let loose at 4:05 p. m. (Rocky Mountain time), and ascended slowly to a height of about 1,000 feet, where it hung for a few moments in equilibrium. A few handfuls of sand thrown out, however, caused it to slowly rise a few hundred feet more, and by repeating the process a series of observations was easily made which can be accepted as reasonably accurate. The balloon changed its course repeatedly as it passed through different currents, and the variations in temperature were marked.

At 4:44 p. m., I was at an elevation of 4,300 feet above El Paso (8,000 feet above sea level), and at a lateral distance of about 6 miles from the waterworks reservoir and the apparatus. At that time several 2-pound charges of dynamite were exploded at that point, in order that I might observe the effect.

A few moments after the first puff of white smoke arose by the reservoir, the sound reached my ears, and at the same time the balloon was perceptibly shaken, trembling for several seconds in a manner that would have been alarming but for my confidence that the fabric and netting were amply strong to withstand the strain from the jarring. At this time the balloon was very close to the cumulo-stratus clouds above, and a moment after the first sound wave reached me an echo came from the clouds, causing the balloon to vibrate slightly again. Several of the 2-pound charges of dynamite were fired at the reservoir during the next five minutes, and after each explosion I experienced the same jarring of the balloon. At 4:49 my ballast was exhausted, excepting a few pounds, which it was necessary to retain for use, if necessary, in avoiding the dangers of a landing in a precipitous region. I therefore opened the valve of the balloon and descended at 4:55 p. m. in a valley on the southeast side of Mount Franklin, about 6 miles (in a direct line) east-northeast from the starting point, and 7 miles northeast from El Paso. After folding the balloon and depositing it in a safe place, I started for El Paso around the south end of the mountain. I soon met Mr. Jennings with horses, and after sending word to Mr. Fairchild, who was farther up the valley, we proceeded to the city. On the outskirts of the city we met Dr. D. M. Appel and a party of men from Fort Bliss, whom Maj. Henton had very considerably detailed to render any necessary assistance.

The record of observations made are given below.

Observations made September 17.

Altitude above—		Temper- ature (cor- rected).	Rela- tive humid- ity.	Dew- point.	Abso- lute humid- ity.	Wind direc- tion.	Wind velocity (approximate).	Time (local).
Sea level.	El Paso.							
<i>Feet.</i>	<i>Feet.</i>	°		°	<i>Grains.</i>			<i>P.M.</i>
3,900	200	89.	23	46	3.539	0	0	4.00
4,200	500	86.	30	50	4.077	N.	Very light.	4.07
4,700	1,000	80.	24	40	2.849	NW.	Very light.	----
5,200	1,500	75.4	31	43	3.178	W.	Light.	----
5,800	2,100	72.9	30	40	2.849	W.	6 miles per hour.	----
6,400	2,700	72.9	30	40	2.849	S.	10 miles per hour.	4.35
7,000	3,300	71.9	30	38	2.616	W.	Light.	----
7,200	3,500	67.9	31	36	2.457	SW.	Light.	----
7,500	3,800	66.	30	34	2.280	SW.	Very light.	----
8,000	4,300	60.	65	48	3.8015	W.	Very light.	4.44
*4,300	600	81.	29	45	3.415	SE.	6 miles per hour.	6.00
†3,717	0	83.	26	44	3.295	E.	2 miles per hour.	‡6.00

*Mt. Franklin.

†At El Paso.

‡Weather Bureau.

NOTE.—The exceedingly dry condition of the atmosphere immediately above El Paso at the time these observations were made and during the subsequent experiment, may perhaps be better comprehended by those not conversant with meteorological figures, when it is stated that during such conditions, if rain fell from the clouds overhead in quantities sufficient to make 12 inches of rainfall in a more humid climate (the entire average annual rainfall at El Paso is less than 12 inches), but should descend so slowly or in such small drops as to be entirely evaporated in the air before reaching the earth, the average relative humidity would still be less than 35, or about one-half the average humidity throughout the Northern States. An amount of water equal to a flood about 2 feet in depth over all the surface of the land in that locality, could be evaporated in the air before it would become as moist as the atmosphere generally is throughout the Eastern and Northern States.

It will be seen that while the relative humidity was considerably higher in the upper strata than at the surface, yet the absolute humidity increased only slightly, and the dew point was lower; the increase in relative humidity being due mostly to the decrease in temperature. If the cloud stratum, which was very high, could have been reached, a greater amount of moisture would doubtless have been found, but the presence of a stratum of exceedingly dry air 5,000 feet thick, below the moist strata, would effectually prevent any considerable quantity of rain from reaching the earth below, even if heavy clouds were condensed above and caused in some way to precipitate their moisture.

In fact, it is a matter of frequent occurrence in this region to see rain falling in torrents from heavy nimbus clouds high above the earth, but evaporating so rapidly in the descent as to disappear entirely before reaching the earth, sometimes even before it has fallen a half or a third of the distance. If the jarring together of the particles of moisture in suspension in the air and the consequent releasing of latent heat is an important factor in the disturbance of the atmosphere for generating a storm center, it would seem that such a locality as the Rio Grande valley at El Paso, where the moist strata are almost always at so great a height, would be a peculiarly difficult place in which to obtain the desired effect. Upon the Staked Plains, and in the southern part of Texas, the moist cloud strata were much lower, even during the driest days. This is demonstrated by the fact that on numerous occasions when the air at the surface of the earth was exceedingly dry, but with broken cumulus clouds floating overhead, the explosion of a few pounds of dynamite on the ground would jar showers from the clouds, and the drops fell to the earth, sometimes inside of ten or twelve seconds, showing that the clouds were so low that the wave of concussion had reached them and the resultant drops had fallen from the cloud to the ground in that time. If, again, the effect of the explosion of the balloons directly in the moist currents is important, another difficulty in the way of successful work presents itself at El Paso; for the altitude of the moist currents is so great and the dry surface winds have such a high velocity that it is difficult to get a balloon to attain a sufficient height before exploding. The test, therefore, at El Paso was to be a peculiarly severe one under any circumstances.

Moreover, upon the following day, the 18th, a strong wind set in from the southwest, rolling vast quantities of hot, dry air from the great desert region,

the Sahara of North America, which lies just west of El Paso and the Rio Grande valley and extends to the Sierras and the coast of the Gulf of California. In many portions of this great desert rain is practically unknown and the wind from that quarter, which set in at El Paso during the morning of the 18th, was so hot and dusty that the sky took on a copper hue; every vestige of the showers which had recently fallen in the vicinity were driven far away to the east, and, so far as the conditions of the atmosphere were concerned, the test might as well have been made in the very midst of the desert instead of on its border.

However, despite the unusually unfavorable condition, it seemed best to proceed with the experiment and observe what effect, if any, the explosions would produce; any postponement in order to secure normal conditions being especially undesirable, on account of the fact that a large number of prominent people from Texas, New Mexico, and Arizona, and from Chihuahua and Sonora, Mexico, were present, by invitation of El Paso, to witness the experiment, and would be inconvenienced by the delay.

At 8 a. m. we were joined at the balloon apparatus by a detachment of United States troops from Fort Bliss, which, at my request, had been detailed by Maj. Henton to assist in the work. The detachment consisted of twenty privates and two noncommissioned officers under the command of Lieut. S. Allen Dyer, of Company D, Twenty-third Infantry, U. S. Army, and rendered valuable assistance.

Mr. Jennings, accompanied by ten of Lieut. Dyer's men, proceeded to the summit of Mount Franklin, where all the preparations had been made for maintaining a continuous fire of dynamite and rackarock throughout the day.

In the meantime, the hydrogen-generator was recharged and balloons and fittings were unpacked. The balloons were first charged with oxygen from the cylinders which had arrived on the preceding day and were then attached to the hydrogen-generator for the completion of the inflation.

At 10:30 a. m. the temperature on the mesa was 84° , the relative humidity 38° , dewpoint 59, and the barometer indicated a pressure of 30.11 inches, having slowly risen during the preceding forty-eight hours.

At 10:35 the first explosion was fired from Mount Franklin by Mr. Jennings and his men, and from that time until 7:30 p. m. the explosions at that point occurred at intervals of three minutes; 206 charges of from 2 to 50 pounds of dynamite and rackarock being fired, and 550 pounds of the explosives being used. Between 11 a. m. and 12:30 p. m. 2-pound charges of dynamite were exploded at intervals of two minutes on a hill 1,000 yards west of the gas generator. About fifty charges were fired at this point.

At 1:30 p. m. the first balloon, containing 525 feet of oxy-hydrogen gas, was exploded at an altitude of 3,000 feet, and from that time until 5:30 p. m., eight balloons of the same capacity were exploded at thirty-minute intervals and at altitudes varying from 500 to 4,000 feet. From 2 to 4 p. m. about fifty charges of dynamite were fired at short intervals on the mesa southeast of the generator, and bombshells were thrown from a mortar at intervals of five minutes during that time, and exploded at altitudes of 500 to 1,000 feet.

From 7:30 to 8 p. m. the bombs from the mortars were fired at intervals of one minute each, exploding high in the air with great force. At 8 p. m. a balloon, containing 525 feet of the explosive gases, was fired at an altitude of 2,000 feet and a 12-foot balloon of 950-foot capacity was exploded at an altitude of 4,000 feet. This exhausted all the available material, and the firing ceased. Between the hours of 10:30 a. m. and 8 p. m. 370 heavy explosions had been made, the intervals between averaging one and two-thirds minutes.

During the day the wind had blown from the west and southwest from the dry region, at an average velocity of 7 miles an hour, and at 8 p. m., when the firing ceased, was still blowing lightly toward the northeast. At this time clouds and lightning could be seen in the east and northeast, the direction toward which the wind had been blowing during the firing. Soon after 8 p. m. the wind died out, rising again very lightly soon after 10 p. m., but coming then from the northeast, a direction diametrically opposite to that from which it had been blowing before; broken clouds began to appear, coming from the northeast over Mount Franklin. At 11 p. m. clouds also began to form overhead, a thin stratus cloud gradually spreading and growing heavier until at 12.30 a. m. two-thirds of the sky was thickly overcast and every appearance indicated rain. At this time the temperature was 69.5° , the relative humidity 64, absolute humidity 5.12 gr., and dew point 57, and the barometer indicated a pressure (corrected) of 29.94 inches, having fallen .17 of an inch during the firing and showing a net fall of .16 of an inch during the twenty-four hours ending at 11 p. m.

Soon after midnight the clouds began to pass off to the south, no rain having

fallen, and at 3:30 a. m. the barometer, which had fallen to 29.91, began to rise. By sunrise the sky was clear, except for the clouds which could still be seen in the southeast, and the indications for rain had disappeared. A heavy dew had fallen during the night, an occurrence which, I am reliably informed, had never been known before in that region.

From inquiries by mail and telegraph on the morning of the 19th, it was ascertained that soon after midnight rain had begun to fall *within a few miles of El Paso*, to the south and southeast, evidently coming from the clouds *which had formed over the city*, during the explosions, and, between midnight and morning, a heavy rainstorm had passed down the Rio Grande valley, copiously wetting the valley, including a few miles of the contiguous portions of Texas and Mexico.

It is a circumstance worthy of careful notice that the direction of the course of this storm seems to have been directly opposite to the constant course of the rainstorms which occur in that region and which are almost invariably from the Gulf country in the east and southeast, toward the arid mountain region to the west and northwest, while this disturbance evidently originated in the midst of this dry region about El Paso, after leaving El Paso traveling down the Rio Grande valley from northwest to southeast, a direction from which only the driest winds are expected.

The materials consumed in the El Paso test were as follows:

From the stores of the expedition:

Nine 10-foot diameter balloons, at \$25-----	\$225. 00
One 12-foot diameter balloon, at \$35-----	35. 00
1,600 pounds sulphuric acid, at \$1.32 per cwt-----	21. 12
3,000 pounds cast-iron borings, at 50 cents per cwt-----	15. 00
400 electrical exploders, at 3 cents-----	12. 00
Rope, wire, etc-----	8. 00
150 pounds of B rackarock-----	25. 00
<hr/> Total-----	<hr/> 341. 12
Salaries of members of expedition during twelve days spent at El Paso--	192. 00
<hr/> Total cost to Government-----	<hr/> 533. 12
 Expenses paid by outside parties (by the city of El Paso):	
500 pounds of dynamite, at 15 cents-----	75. 00
2,000 cubic feet oxygen gas, at 5 cents-----	100. 00
6 dozen bombshells, at \$17 per dozen-----	102. 00
Expressage on oxygen and bombs and return freight charges on cylinders (estimated)-----	250. 00
Hotel bill of party (estimated)-----	90. 00
Teams and labor (estimated)-----	150. 00
<hr/> Total-----	<hr/> 767. 00
<hr/> Total expense of El Paso test (approximate)-----	<hr/> 1, 300. 00

Among those present at the El Paso experiment were: Mayor Richard Caples, of El Paso, and the mayor of Ciudad Juarez, Chihuahua, Mexico; Maj. James Henton, Twenty-third Infantry, U. S. Army, commanding officer at Fort Bliss; Dr. D. M. Appel, post surgeon at Fort Bliss; Lieut. S. Allen Dyer, Company D, Twenty-third Infantry, U. S. Army, acting signal officer, Fort Bliss; Capt. Juan S. Hart, editor, and J. A. Ponder, city editor, El Paso Daily Times (representing the Associated Press); the editors of the El Paso Daily Tribune and El Paso Daily Herald; Hon. George W. Fulton, jr., Colman-Fulton Pasture Company, Gregory, Tex.; Dr. Y. M. Yandell, El Paso, health officer; Mr. N. D. Lane, El Paso, observer U. S. Weather Bureau; Mr. William A. Bowen, secretary San Antonio Commercial Exchange; Lieut. Bartlett of the Artillery, from Fort Sam Houston, San Antonio, and Mr. Herbert Stranathan, of the staff of the St. Louis Post-Dispatch.

THE SAN DIEGO EXPERIMENT.

On August 30, Mr. Robert J. Kleberg, representing the King Ranch (of 700,000 acres) near Corpus Christi, Tex., and Hon. N. G. Collins, of San Diego, had called at the C ranch, Midland, having come to investigate the outcome of the Midland experiments and to urge that some experiments be made by the Government

party, in their locality. These gentlemen stated that their region was suffering from very severe drought, and that the results of a successful test would be of great immediate benefit to the country.

Since at this time (August 30), the appropriation could not afford the expense of a test in the southern part of the State, it was necessary for me to inform the gentlemen that it would be impossible for you to pay the expenses. They requested that I furnish them with some idea of the expense of an experiment such as they proposed, and that I mail them, as soon as convenient, a more detailed estimate of the expenditures necessary, and meanwhile they would return to Corpus Christi and arrange for the payment of the expenses by those in the neighborhood who were interested in the matter. This I did, and stated that we could reach Corpus Christi on or before September 24. On September 9, I received the following telegram from Mr. Kleberg:

"CORPUS CHRISTI, TEX., September 9.

Have ordered everything by wire. Money ready to pay all expense.

R. J. KLEBERG."

And on September 12 the following:

"Everything ordered. Come to Corpus Christi.

ROBERT J. KLEBERG."

Having reported their proposal and plans to you and received your approval, I arranged to go to Corpus Christi immediately after completing the work at El Paso.

Hon. George W. Fulton, Jr., came to El Paso from Corpus Christi, representing the parties who had subscribed toward the expenses of the proposed tests there, to witness the El Paso experiment and to complete arrangements for the operations in the southern part of the State. At his request, Gen. Stanley detailed Lieut. Dyer, with two non-commissioned officers and eight privates from Companies B and D, Twenty-third Infantry, at Fort Bliss, to assist us in southern Texas.

Through the courtesy of Mr. E. G. Bleker, general manager of the Texas lines of the Southern Pacific Company, and Mr. R. W. Andrews, passenger agent of the San Antonio and Aransas Pass Railroad, I obtained free transportation for the fifteen members of our party and our freight, from El Paso to Corpus Christi (780 miles) and return.

After loading and shipping our freight, we left El Paso, with Lieut. Dyer and his men, on September 23. We reached San Antonio, the following morning and were met by Mr. William A. Bowen, secretary of the San Antonio Commercial Exchange, who took us to the rooms of the exchange where a number of representative citizens of San Antonio, including President Hugo of the Board of Trade, Mr. R. W. Andrews of the San Antonio and Aransas Pass Railroad and the editors of the city papers, had gathered to talk with us concerning the experiments and the prospect of our being able to come to San Antonio for a test in the near future. That region, like the rest of the State, was experiencing an unusually dry season. At 1:30 p. m., we started on to Corpus Christi, reaching that point at 8 p. m. During the afternoon, a heavy rain had set in from off the Gulf of Mexico and the weather continued stormy for several days. On account of the rainy weather, we postponed, indefinitely, any important experiment, but on September 26, an unimportant trial was made of some bombs which had been received from New York. At 3 p. m., twelve of the bombs and two mortars were carried in a carriage to an elevated spot about 1 mile west of the Corpus Christi Railroad station where they were unpacked and the mortars set up.

The weather was threatening, several slight showers having fallen during the afternoon, and cumulus clouds passing overhead at intervals. A brisk wind was blowing from the northeast, and the clouds were moving rapidly. Just as a heavy cumulus cloud came well overhead, four bombs were shot from the mortars and exploded at a height of about 500 feet. No rain was falling at the time, and it could be plainly seen that none was falling anywhere in the vicinity. A few seconds after the explosions, scattered drops began to fall, and as the cloud passed rapidly on towards the southwest, the rain could be seen falling from it in a brisk shower. When another cloud came overhead, four more bombs were fired, and the same result was observed except that the shower was heavier than the first. Finally a heavier cloud than usual passed over, and the explosion of four more bombs was immediately followed by a downpour which lasted for several minutes and soaked the party to the skin before they could enter a carriage. As this shower passed on southwest, it could be seen to grow heavier and spread out over a much broader path.

As the rainy weather continued, the advisability of abandoning the experiments in that region was discussed; but it was deemed advisable to wait a few

days, and see how long the wet weather would continue. Camp equipage and commissary supplies were provided by the citizens' committee, and on September 28, the expedition proceeded to San Diego, a small station on the Mexican National Railroad, the county seat of Duval County, 55 miles west of Corpus Christi, where the drought had been very severe and there had been a deficiency of rain for several years. Very little of the rain which had fallen on the coast during the preceding days had penetrated so far inland, and the fall there had been much less.

Camp was pitched near a windmill pump, $1\frac{1}{2}$ miles northeast of the San Diego station, and two hydrogen-generators were set up. The rainy weather gradually cleared up, the last shower falling on the 3d of October, when the Weather Bureau office at Corpus Christi recorded 0.10 of an inch and a slight sprinkle fell at San Diego. On October 4, a "norther" arose which quickly drove away every sign of rain. "Norther" is the name applied in Texas to cool, dry winds which sweep down from the north over the hot, dry plains, generally with a velocity of from 10 to 20 miles an hour. Having their origin in the elevated arid regions of the Northwest, and passing over thousands of miles of dry prairie country before reaching Texas, the "northers" or "dry northers," as they are frequently called, are, by all means, the driest winds that ever blow in that region. The "northers" are not shallow currents, as many of our surface winds are, but, generally, as we found by sending small balloons up into them, they extend upwards to a height of two miles or more, forming a thick stratum of extremely dry air—a condition of the atmosphere under which, according to the theories we were testing, as well as to the accepted principles of the formation of rain-storms, it would seem to be utterly impossible to produce rain by any means.

On the 10th the "norther" subsided, but another was foretold for the 12th by the Weather Bureau office at Corpus Christi. This one dissipated, however, before reaching Texas, and on the 15th, being informed by the Weather Bureau that all indications promised normal, dry weather, we began work.

After a full discussion of the matter with Lieut. Dyer, the following plan was decided upon:

First. The principal explosions should take place at night time, on account of the fact that the heavy winds which prevail during the day, subside soon after sunset and the night is comparatively quiet, therefore offering fewer difficulties to the manipulation of the balloon apparatus. It was also thought that the high winds of the daytime might tend to dissipate the effect of the explosions.

Second. A preliminary firing, with the explosions occurring at intervals of five or ten minutes, should be kept up during several hours, commencing early in the morning of Friday, the 16th of October, and continuing through the day and following night, in order to observe the effect of explosions occurring at considerable intervals as compared with a shorter series of much more rapid explosions which should keep up a constant agitation of the air.

Third. On the night of October 17, taking advantage of whatever meteorological disturbances the preliminary firing had caused, the principal and final operation should take place, consisting of about 1,000 very heavy explosions occurring in rapid succession.

The night of October 15 was perfectly clear, and at 6 p. m., the barometer indicated a pressure of 30.07 (corrected).

At 1 a. m., Friday, October 16, with the wind blowing from the southeast at about 5 miles per hour, the firing of dynamite and rackarock was begun and was continued until 3 a. m., the explosions occurring at comparatively frequent intervals, five dynamos being used. The first balloon was exploded at 2 a. m., a second at 4 a. m., and a third at 7 a. m. In the mean time, three hundred 21-pound charges of dynamite and rackarock had been fired. The firing of dynamite was then continued in 3-pound charges, at five-minute intervals, until 12:30 p. m.

During the 16th, the wind continued to blow from the southeast, attaining a velocity of 15 miles an hour. In the afternoon, a few cumulus clouds passed overhead, but, as night approached, they gradually disappeared. At 6 p. m. the barometer stood at 30.02, having fallen slightly in the twenty-four hours. At 5 p. m. the firing of five-minute explosions was renewed, the charges consisting of $2\frac{1}{2}$ pounds of rackarock and a quarter pound of dynamite, the use of a portion of dynamite having been found effective in producing a better explosion of the rackarock.

At 6 p. m. a 10-foot balloon was exploded and the firing of dynamite was continued till 8 o'clock. At 11 p. m., a second 10-foot balloon was fired and three more followed at intervals of seventy-five minutes each, the last being exploded at 3 o'clock a. m. At that time, (the morning of Saturday, the 17th,) the sky was clear, the wind was fresh from the south, having blown from that direction since 10 p. m., and the barometric pressure was 30.09. The Weather Bureau reports

show that a region of several hundred square miles directly northwest of us had become overcast with clouds during the night.

There was no more firing throughout the day of the 17th until evening, but preparations were immediately begun for the formidable task of firing, with as little danger of accident as possible, 7,000 cubic feet of oxy-hydrogen and 800 charges of dynamite and other explosives; 1,500 pounds of rackarock and dynamite were bound in bundles of three cartridges of the former ($2\frac{1}{4}$ pounds) and one small cartridge of the latter ($\frac{1}{4}$ pound) with the electric exploder inserted in the dynamite and short wires extending, ready to be attached to the electrical conductors from the dynamos. One hundred 2-pound cartridges of powder were prepared for a cannon and the work of generating gas for the balloon explosion was also steadily pushed.

The dynamo dischargers and connecting wires were rearranged so that the explosions would not be so close together, as the great concussion caused severe headache to the operators. Between 5 and 6 p. m., a few charges were fired to test the new wire.

At 6 p. m., the thermometer indicated a temperature of 79° , the barometric pressure was 30.11 and the barometer was steadily rising; the relative humidity was 48, wind fresh from the southeast, and sky clear, but for a slight patch of light clouds, evidently 50 miles away, on the northwest horizon, in the direction toward which the wind had been carrying all the disturbances of the firing of the preceding thirty-six hours. This cloud had been observed since 2 p. m., and since that time had not changed its position. A careful observation during the four hours showed that it was not approaching, but evidently rested stationary. During the afternoon, fearing that the distant spot of cloud might be an indication of a "norther," which I knew would render futile an attempt to produce rain by any means at that time, I carefully questioned a number of the most intelligent citizens and ranchmen of that locality, who were present to witness the experiment, and received positive and unanimous assurance, first, that the cloud spot was not a forerunner of a "norther," being entirely different from the dull, lead-colored clouds which sometimes accompany a very cold "norther," and also, secondly, that there was not the slightest chance of rain from that cloud or from any clouds in that direction, as they never had rain from that quarter.

Believing, however, that any effect of the explosions upon the atmosphere must have been carried in that direction, and recalling the reversing of the wind at both Midland and El Paso, after the firing at those points, we watched the cloud very closely. Several times during the afternoon, lightning was seen beneath it. A 10-foot balloon sent up at this time, to ascertain the direction of the upper currents of the air, revealed the fact that at an altitude of about 4 miles there was, as is usually the case, a current moving in the opposite direction to the wind on the surface, that is, from northwest to southeast.

At 9 p. m. all arrangements had been completed and the following paraphernalia was in position, viz:

Six dynamos with two double conductors leading from each to a safe distance, for the explosion of dynamite, these dynamite batteries being arranged in a semi-circle of three-fourths of a mile diameter, southeast of the balloon apparatus.

Five mortars for throwing 21-pounder bombshells into the air, these being located to the left of the dynamite line.

One 12-pound cannon to the left and north of the mortars.

Beside each dynamo was a pile of rackarock, consisting of about one hundred $2\frac{1}{2}$ -pound charges for each dynamo, and ready primed with electric exploders. One hundred bombs were piled beside the mortars, which had been sunk in the ground to prevent accidents from explosions. One hundred cartridges were also piled beside the cannon. At the gas apparatus four balloons had been filled and were anchored, with fuses inserted ready for firing, and two more were in the course of inflation.

The dynamite battery was manned with two men for each discharger, one of whom should attach the charges to the wires, and the other work the dynamo. The wires were so arranged that each dynamo could explode two of the heavy rackarock charges in rapid succession, every minute, and every precaution was taken to guard against accidents. The mortars and cannon were handled by Lieut. Dyer and two men—Mr. Fairchild and Mr. Casler; I operated the balloon apparatus, and Mr. Jennings had charge of the dynamite batteries.

At 9:45 p. m., the first balloon was started off. As it ascended, easily visible by the fact that it was a moonlight night, the men at the batteries made ready, and the moment the flash of the explosion was seen, the dynamite and mortar batteries and the cannon were exploded, the flash of the balloon serving as a signal for these explosions, the roar of the ground explosions mingling with the crash

of the explosion of about 1,000 cubic feet of oxy-hydrogen gas produced a concussive effect of tremendous force, and the ground was shaken for miles, as we afterwards learned, in every direction.

From 9:45 to 11:30 p. m., the explosions were continued at the rate of ten a minute. The men were instructed to bunch the firing into volleys, so that at times a dozen explosions occurred in half as many seconds.

The hundreds of spectators who had come from San Diego and other towns near by, crowded together in a frightened mass in the open space in the midst of the camp. As soon as they were assured that passage was safe along the roadway a large majority of the spectators started for their homes.

At midnight, after the rapid firing had ceased, those who had remained, also left the camp, the believers in "rainmaking" being sadly disappointed and all being positive that the test was a complete failure, for the sky overhead was never clearer and the moon never shone more brightly. The fact that the edge of the light cloud in the northwest seemed to be nearer, did not have the slightest weight with any of the many ranchmen present, for they were confident that no rain could come from that quarter, and all were convinced that the test was a failure.

At 6 p. m., the barometer had indicated a pressure of 30.11 inches, which is above the normal. Since that time it had continued its steady rise and now showed 30.24 inches, and was still ascending. The relative humidity had risen from 48 at 6 p. m., to 84 at 10.15, and 92 at midnight. The temperature had fallen in that time from 79° to 65.5°. The absolute humidity of the air had increased from 5.018 gr. per cubic feet at 6 p. m., with the dew-point at 56°, to 6.35 gr. at midnight, with the dew-point at 63°. The wind continued from the southeast at about 4 miles per hour on the surface, with a greater velocity above, as was indicated by balloon movements. The sky was perfectly clear except for the cloud in the northwest, which, after resting stationary for nine or ten hours, had evidently begun to approach at about 11 o'clock, after the heavy firing had been in progress an hour and fifteen minutes.

Up to midnight, four 12-foot balloons containing 3,500 cubic feet of oxy-hydrogen gas had been exploded and about eight hundred charges of other violent explosives.

Several times a heavy ground explosion was observed to create a forcible upward current, taking the form of an eddy or whirlpool, accompanied by a ring of smoke, which rose with a whirling motion high into the air attended with a peculiar sound, something between a whistle and a hoarse moan, heard for several moments after the explosion.

After midnight, balloons alone were used, being sent up and exploded at intervals of forty-five minutes, the approach of the clouds, meanwhile, being watched with the greatest interest. At 2 a. m., when they had risen to an altitude of about 25° from the horizon, they seemed entirely to cease approaching and began to spread out steadily in both directions from a point directly northwest, of the observers. By 3 a. m., that which had been a small cloud in the northwest, had grown and spread out, extending wings to left and right which circled around us both to the west and east in what soldiers term a "flanking movement," until the clouds extended all around three sides of us, to the west, north, and east.

Meanwhile the clouds, for something more than an hour, had not advanced toward the zenith, the sky being entirely clear down to the edge of the clouds, which defined an irregular line extending from a point in the southwest, around three sides of us, at an elevation of about 25° from the horizon, to a point in the southeast. Up to 3:50 a. m., the clouds kept creeping around us in both directions, in an unusual manner, starting from a center in the northwest where the formation and growth seemed to originate.

At about 2:30 a. m., while the conditions were as described above, a 10-foot balloon was sent off with the fuse set for about fifty seconds. As it rapidly ascended, we were surprised at its unusual actions, for instead of floating steadily away, as usual, upon the inclined path by which the wind would carry it, this balloon started on a slant toward the northwest and when it had reached a height of a few hundred feet, turned sharply back toward the southeast and then made several other changes of direction before exploding at an altitude of about 1,500 feet.

The actions of the balloon showed plainly that there was some unusual disturbance of the air. Our balloonist had never seen such action before. When the next balloon was released, therefore, at 3:20 a. m., while the clouds were still strangely holding off but extending around us, several of our party took posi-

tions at different spots to observe the course which the balloon would take. There were exclamations of amazement on all sides when, after ascending toward the north about 200 feet, it turned sharply to the south and passed directly overhead in an irregular waving course, then turned again toward the northeast and pursued an unsteady course in that general direction, turning back and forth and to one side and the other, making spirals and zigzags in every direction, until it finally exploded at a height of about 3,000 feet, a little to the northeast of the starting point. The sight of the ascending balloon carried noiselessly hither and thither in the moonlight, by unseen and unexplained forces was almost uncanny and positively alarming for the moment, in its suggestions of all manner of whirlwinds and cyclones in embryo. Immediately after the explosion of this balloon as well as that of the one preceding it, flashes of lightning were seen in the distant clouds by those who were watching them.

At 3:30 a. m. it was noticed that the sky to the south was also filling with clouds and only at the zenith was it clear. This attracted attention to the sky overhead where we were soon able to see the manner in which the clouds were forming; for at about 3:35 we saw a spot of vapor appear in the clear sky overhead, then spread out and rapidly thicken until within five minutes it had become a dark cloud entirely obscuring the moon. This cloud slowly drifted to the south and other spots of vapor began appearing here and there, growing in the same manner. In fifteen minutes the sky was completely "filled up" with dark clouds.

It was now a few minutes before 4 a. m., and the barometer stood at 30.30 inches. The wind, which had sunk to a light breeze, now changed from the southeast to the northwest, and the clouds, which covered the entire heavens, could be seen moving in the same direction.

At 4 a. m. the last balloon was exploded. It had been carried half a mile to the south when the explosion occurred, and rain appeared to begin to fall at that point immediately after the explosion. At 4:05, some bombs and a few charges of rackarock were exploded and immediately scattered drops began to fall. In five minutes a steady rain was falling and in another ten minutes, the water was pouring down in torrents. The rain continued falling until a few minutes before 5 a. m., and the rain-gauge registered .47 of an inch in that time. A little before 5 o'clock the wind had risen strongly from the north and the clouds were carried rapidly south before it. The rain ceased as the clouds passed off, and the fact was revealed that there was not a single cloud of any kind following the one storm cloud from which the rain had fallen. Fifteen minutes after the rain ceased, the northern half of the sky was entirely clear, and in an hour there was hardly a cloud in sight. Our weary men "turned in" after seventy-two hours of work with only five or six of sleep.

This rainfall was the only one observed by the office of the Weather Bureau at San Antonio from the 4th day of October to the 16th of November. The material used in the San Diego experiment was as follows:

From the stores of the Government expedition:

Fifteen 10-foot balloons, at \$25.....	\$375.00
Five 12-foot balloons, at \$35.....	175.00
3,600 pounds sulphuric acid, at \$1.32 per cwt.....	47.52
2,000 iron borings, at 50 cents per cwt.....	10.00
100 pounds rackarock.....	16.00
Wire, etc.....	10.00

Cost to Government.....	\$633.52
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Materials furnished by the King Ranch and others in Corpus Christi, San Diego, and vicinity (cost estimated):

2,000 pounds of rackarock.....	\$320.00
5,000 cubic feet oxygen gas.....	250.00
120 bombs.....	170.00
250 pounds cannon powder.....	25.00
500 pounds dynamite.....	75.00
2,000 pounds iron borings.....	10.00
1,500 electrical exploders.....	45.00
200 feet time fuse and caps.....	5.00

Total.....	\$900.00
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Total cost of materials used (approximated).....	\$1,533.52
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The latter persons also paid the salaries and expenses of the party during the time spent at Corpus Christi and San Diego, and the traveling expenses from El Paso and return, a sum amounting to \$736.

During the following day a number of gentlemen, who had watched the results of the experiment, came to our camp to offer their congratulation on what they considered "a complete success in producing rain under the most unfavorable circumstances," and to bring me reports from various points near by where the rainfall had been much heavier than at our camp.

From Judge James O. Luby, Dr. Lincoln B. Wright, and Mr. Valverde, agent of the Mexican National Railroad, at San Diego, I received the following reports, which, in the absence of the officers of the Weather Bureau in that region, are as reliable as could be obtained. The original expressions are used:

Moose Ranch, 23 miles northwest, no rain.

Mathis, 30 miles northeast, no rain.

Banquete, 25 miles east, no rain.

Corpus Christi, 50 miles east, no rain.

Peña, 50 miles southwest, no rain.

Skidmore, 40 miles north northeast, "good rain."

San Antonio, 115 miles north, slight rain (.19 inch).

Paul Hennery, 6 miles north, "very heavy rain."

Laredo, 85 miles west, "good rain."

Realitos, 30 miles southwest, "light rain."

Parie Ranch, 27 miles southwest, "heavy rain."

Benavides, 18 miles southwest, "pretty good."

Hoffman Ranch, 7 miles southeast, "very good rain, water ran."

Thomas Collin's, 10 miles southeast, "good rain."

Paleta Blanca, 16 miles southeast, "heavy rain."

Other points to at least 25 miles southeast, "heavy rain."

Many points south of San Diego reported that the rainfall was "very heavy" in that direction, the water "running" and "standing in the hollows."

According to the theories under test, the fact that the rainfall extended as far north as San Antonio (115 miles), where there was a slight fall, would not at all indicate that the rain was not occasioned by local causes, for the effects of the firing, whatever they may have been, must certainly have been carried as far and farther than that point by the wind which blew steadily in that general direction during all the firing.

That the "norther" had no connection with the formation of the storm would seem to be clearly indicated by the fact that the clouds, which afterward developed and produced the rainfall, were in sight at least eleven hours before the "norther" reached San Antonio, 115 miles north. The rain was local in character, being restricted to south-central Texas and being central and much the heaviest in the immediate vicinity of San Diego. It occurred over the region which, according to the theories of "rainmaking," would be affected by the firing, and during an unusually high and steadily rising barometer.

According to the statement of the agent of the Weather Bureau at San Antonio, the "norther" itself, was brought at least twenty hours before it was due, under normal conditions. He says, "The morning telegraph reports of the 17th indicated a probable 'norther' for this locality within thirty-six to forty-eight hours, and I was surprised to note that it reached here in little more than sixteen hours, a feature which is clearly attributable to the disturbing influences of your experiments at San Diego."

The following forecasts were made by the Weather Bureau during the time of the experiment at San Diego:

Thursday, October 15—Generally fair weather may be expected for forty-eight hours in the Mississippi Valley and the Gulf States. 8 p. m.: For the Gulf States, generally fair.

Friday, October 16—For the Gulf States, generally fair. 8 p. m.: For the Gulf States, generally fair.

Saturday, October 17—8 a. m.: Another clearing condition of great magnitude has moved from the Pacific coast to Wyoming, and will dominate the weather west of the Mississippi River for the next forty-eight hours.

Forecast until 8 a. m. Sunday—For Alabama, Mississippi, Louisiana, and Eastern Texas, generally fair; stationary temperature, except slightly warmer in northern portions, winds becoming southerly. 8 p. m.: Another clearing condition from the Rocky Mountain plateau to Colorado, increasing in magnitude, and dominating the weather west of the Mississippi River. Fair weather may be expected for the middle and upper Mississippi Valleys and west of the Mississippi River, also in the Atlantic and Gulf States.

Forecast until 8 p. m., Sunday.—For Louisiana and Eastern Texas, generally fair; slightly cooler, except stationary temperature on the Gulf; winds becoming northerly.

On October 19 our party returned to Corpus Christi, where it disbanded. Free transportation was furnished by the railroads for the various members of the expedition to El Paso, St. Louis, and Chicago, and for our apparatus and unused material to St. Louis, where I returned all the unused chemicals and empty acid drums to Meyer Bros. Drug Company, where I received credit for the same on the account of the appropriation.

In making the experiments at El Paso and San Diego, allowing the regular rates for all transportation of both party and paraphernalia and the full prices on all apparatus and material used, and including all the expenses of the expedition after leaving Midland till it arrived at Washington on the return, a nominal expense of \$6,384.34 was incurred. Of this amount there was an actual expenditure on the part of the Government of \$1,450 (in round numbers), and there was received from the prosecution of the investigations in the form of free railroad transportation, the furnishing of materials and assistants free of charge, and the payment of salaries and other expenses, assistance amounting to a nominal sum of \$4,984.34, saving that amount to the appropriation.

I wish to express my appreciation and gratitude for valuable assistance given by Mr. George C. Smith, of the St. Louis, Iron Mountain and Southern Railroad; Col. John A. Grant, of the Texas and Pacific; Mr. E. G. Bleker and other officials of the Southern Pacific; Mr. R. W. Andrews, of the San Antonio and Aransas Pass, and the officials of the Atchison, Topeka, and Santa Fé, and Mexican National Railroads; also to Mayor Richard Caples, Maj. James Henton, Lieut. S. Allen Dyer, Dr. W. M. Yandell, Dr. Appel, Capt. Juan S. Hart, Mr. Robert J. Kleberg, Messrs. F. Güeydan & Co., Judge James O. Luby, Dr. L. B. Wright, and many other citizens of Corpus Christi and San Diego, who assisted in securing the desirable results of our work at those places. My thanks are also due to the following members of the Twenty-third Infantry, who rendered faithful and intelligent service in the work of the expedition: Sergt. F. Lehman and Privates, S. Adams, M. M. Wolff, and H. McCann, of Company B, and Corpl. A. Gerald and Privates G. Arthur, E. J. Fay, B. F. Ellis, F. Nelson, and M. Morris, of Company D.

I have the honor to transmit herewith copies of certain observations made by the nearest stations of the Weather Bureau during the months in which the experiments were made, statements, concerning the operations and results at El Paso and San Diego, by Mr. Eugene Fairchild, of the expedition, and a few letters of especial interest from prominent citizens of Texas regarding the experiments at which they were present.

Lieut. Dyer has been present with me in Washington during the preparation of this report, in which work he has given valuable assistance. Lieut. Dyer was with me constantly during the experiments at El Paso and San Diego and he authorizes me to say that he concurs in all the statements in this report concerning those experiments.

Very respectfully,

JOHN T. ELLIS.

REPORT OF LIEUT. DYER.

WASHINGTON, D. C., *December 10, 1891.*

R. G. DYRENFORTH,

Special Agent, Department of Agriculture, Washington, D. C.:

SIR: In compliance with special orders received from the War Department, I reported to the Acting Secretary of War, who directed me to report to the Secretary of Agriculture; upon doing so, I was ordered to report to you, and in compliance with your request, I have the honor to submit the following report of my observations and views regarding the Government rainfall experiments at El Paso and San Diego, Tex.:

Having been detailed by the commanding officer at Fort Bliss, Tex., to render Mr. Ellis such assistance, in these experiments, as he might require, I was present when, on the 17th of September, preliminary to the experiments to be made on the following day, a balloon ascension was made by Mr. Ellis to obtain some data concerning the condition of the upper air strata. The observations made

by Mr. Ellis revealed the fact that a thick stratum of extremely dry air existed over the valley, reaching to the altitude of at least 4,000 or 5,000 feet, a condition which could exist only in a few localities, such as the valley in which El Paso is situated, surrounded by high hills and dry, barren country. During the ascension made by Mr. Ellis, a number of charges of dynamite were exploded on the ground near the place of ascension; this was 4:45 p. m. During the firing there were light cumulus clouds above which increased and grew heavier during the evening, and at 9 o'clock p. m. the sky was overcast with thick clouds, and soon after a slight rain fell, the rain-gauge showing a fall of .07 inch.

This was the heaviest and almost the only rainfall in El Paso at any time during the seven months previous to the time of my leaving there on November 30. I am of the opinion that the explosions were the direct cause of the increased amount of precipitation. It was a noticeable fact that this shower was not accompanied by any wind, as it will be found that every rain in that section has always been preceded by wind storms. Many persons who were familiar with the weather at El Paso were of the opinion that this fall of rain was due to the explosions.

During the night, the dry west wind which arose, cleared away all further indications of rain. On September 18, the day on which the experiments were conducted, the sky was perfectly cloudless, with a dry wind blowing, the thermometer registering, at 10 o'clock a. m., nearly 90°, and the barometer being very high, showing a reading of 30.11. The relative humidity was less than 40, and the dewpoint 59.

The experiment began at 10 a. m., and was continued throughout the day until 8 p. m. The wind during the day had blown from the west and southwest at about 8 miles an hour. I noticed that at about 8 p. m., a few clouds had formed and also saw sharp flashes of lightning in the east. Later in the night, more clouds were noticed gathering and forming overhead, and at midnight the sky was black. At this time the thermometer registered 69°, the relative humidity was 64, dew-point 57, and the barometer stood 29.94. Before sunrise nearly all the clouds had passed off and the barometer was rising rapidly. The changes in the atmospheric conditions were such as to show good chances for rain. The heaviest dew known to El Paso had fallen that night, and I was informed by a number of persons that such a heavy dew was never known in El Paso before. While there was no rain in El Paso, reports came in that rain had fallen within 15 miles to the south and southwest, some time after midnight, and it is my opinion that this rain was from the clouds which had formed and gathered over El Paso. I believe that could the explosions have been continued for a longer period, the results desired would have been obtained. After once changing the atmospheric conditions from a usual to an unusual state by artificial means, any cessation of these means would destroy the effects produced and the conditions would again resume their natural state, and, in my opinion, a continual series of explosions should have been kept up until the results desired were obtained. But the material furnished by El Paso was so small in quantity that it was necessary to stop the work before the desired results had been effected.

At San Diego, Tex., on the 15th, 16th, and 17th of October, the experiments were conducted upon a different and more uniform method. On the 16th, the reports from the Weather Bureau showed that the chances of any rain falling at any time in the immediate future were very improbable. It was decided to begin the experiment by firing a few preliminary explosions, using dynamite and rackarock every few minutes during the night, and it was noticed from careful observation that even these comparatively few and scattered explosions caused noticeable changes in the atmospheric conditions. On the 17th, the reports from the Weather Bureau were even more unfavorable than those of the day previous for any prospects of rain. The day was dry, with a cool wind blowing from the south; but again that night similar experiments were carried on as on the night of the 16th; the same if not greater changes were noticed, the Weather Bureau reports showing that an extensive area directly north of the point of operations, and in the direction toward which the wind was blowing, had become heavily overcast with clouds during the night, while at all other points in Texas the sky was perfectly clear.

On the 17th, the day of the final experiment, a telegram was received from the Weather Bureau predicting dry, fair weather, with a rising barometer. It was thought best to finish the work, even though a number of the most prominent people said rain could not come, much less be produced by explosions, under such conditions, and that the result of the experiments would be a pronounced failure. I myself had a long talk with one of the residents and he informed me that rain was never known to fall there with such conditions as then existed, and that it

would be utterly impossible for our party to change the conditions to those suitable for our work, and that it would be better to wait for more favorable conditions.

A series of explosions was kept up continually from about 9 p. m. until 12 midnight. The night was perfectly clear, the only cloud to be seen being a slight patch in the northwest which had lain there all the afternoon. The air was dry and cold, with a slight wind from the southeast. At 12 o'clock midnight this cloud seemed to be growing and began to approach.

I observed a peculiar effect of some of the ground explosions, namely, the formation of rings of smoke, rising and whirling, attended by a distinct rushing and moaning sound, lasting a few moments.

From this time until 3 a. m., several balloons were fired at intervals of a half to three-quarters of an hour. Meanwhile the clouds had been growing steadily and rapidly and vivid flashes of lightning were seen after each explosion. The air was becoming more moist and the clouds had spread around three sides of us. The balloons took unusual courses in their ascents, turning in a number of different directions, thus showing conclusively that there was a strange disturbance of the air; some of the actions of the balloons could be explained in my mind only by the existence of unusual electric conditions.

At 3:50, the sky was black with clouds, very heavy and hanging low, many clouds having formed from clear sky before our eyes. At about 4 o'clock some bombs and a balloon were fired, and almost immediately the rain began to fall, the wind having veered round to the northwest a few minutes before. The rain was soon falling in torrents, drenching everybody and everything. It continued falling for about an hour, when the rain gauge showed that .47 of an inch had been precipitated in that time.

By 6 a. m., a dry north wind had arisen, which drove the clouds away and removed all prospects of further rain.

During the day I talked with a number of the most prominent citizens of San Diego, who informed me that they were astonished at the results obtained; that there was no doubt in their minds that the rain which fell was the direct result of the operations.

The reports which came in by telegraph during the day showed that the rain had extended over an extensive area in south-central Texas, being central and heaviest at the point of our operations and directly north of that point, where the effect of the explosions would be the greatest. The storm was local in character and had come unforetold and unexpected by any office of the Weather Bureau. There was certainly every possible appearance of the rain having been the result of the operations at San Diego.

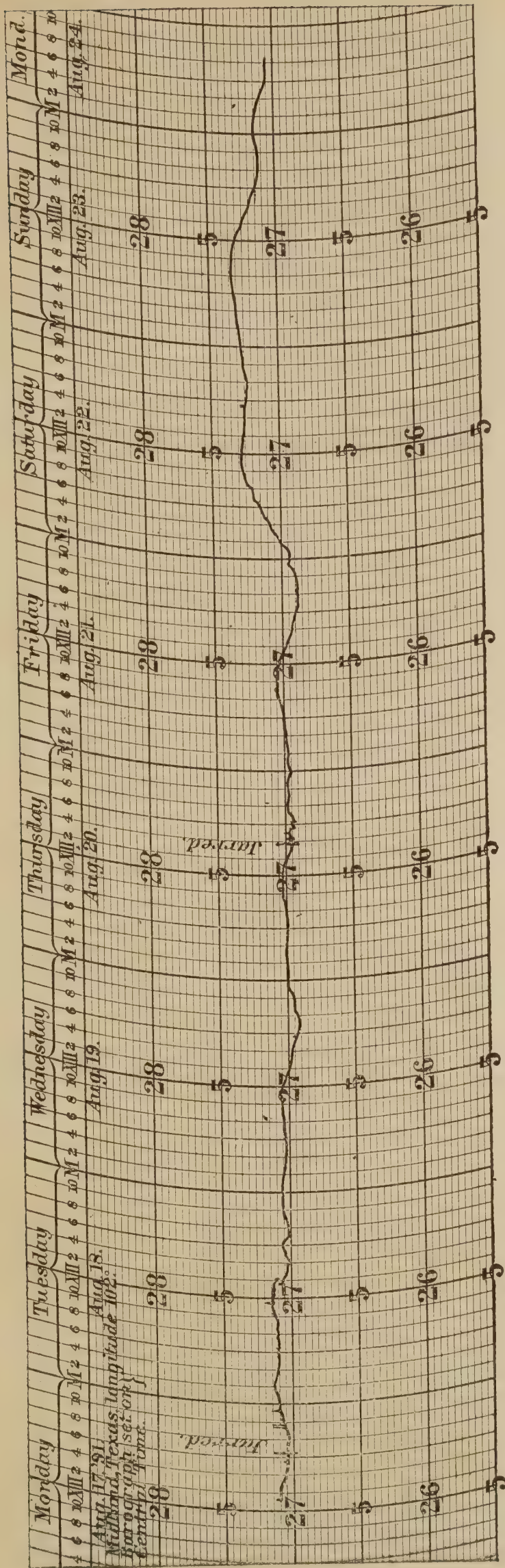
One gentleman informed me that this rain, comparatively light as it was, had been worth to him alone a number of thousand dollars, and that a large area of country in that vicinity had been greatly benefited by it.

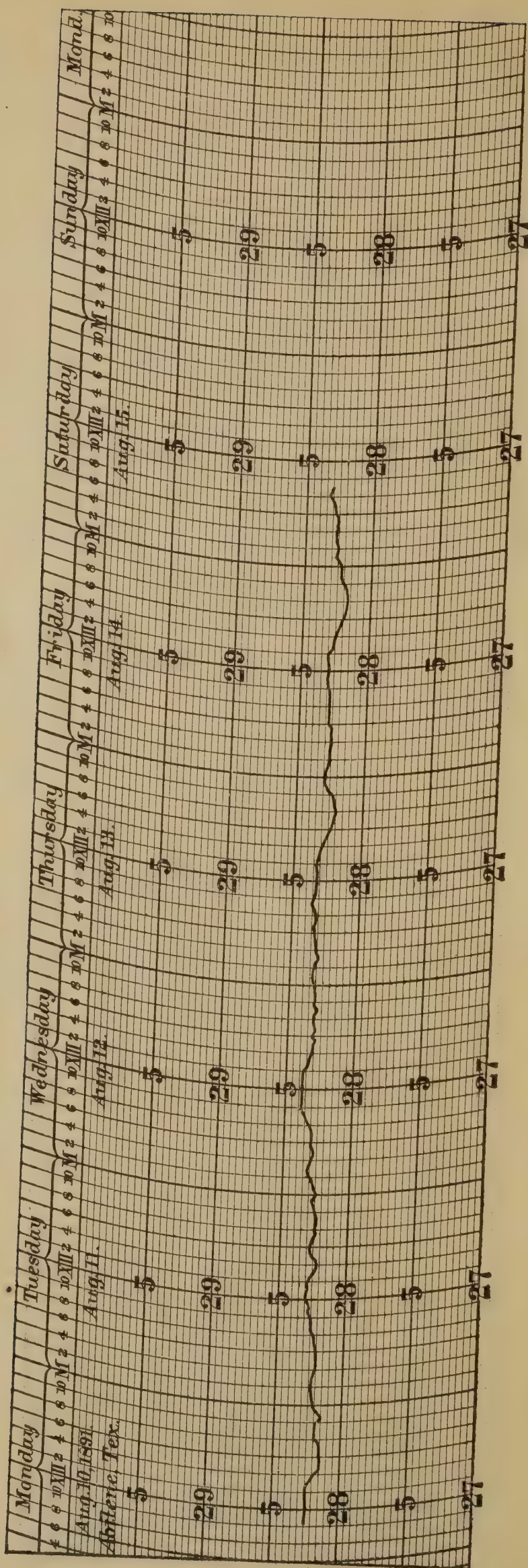
I do not know of a single person who was present while the experiments were made and who saw the conditions under which they were made, who does not express it as his opinion that rain was caused to fall by the operations, and that under the most trying atmospheric conditions. My own observations and experiences during the experiments, have led me to the conclusion and belief that rain can be produced by artificial means and that especially will "rainmaking" prove a practicable and most valuable success when the conditions are favorable for rain; but precipitation, for some reason, does not occur, as is frequently the case, during the driest seasons in the semi-arid regions, and especially during the growing season, when rain is most needed. I know that this opinion is shared by nearly all who have been present at the tests.

I desire to thank Mr. Ellis and the members of his party for their kindness and consideration to myself and detachment during all the operations, Mr. Ellis being ready at all times to give me any desired information or assistance.

Very respectfully, your obedient servant,

S. ALLEN DYER,
First Lieutenant, Twenty-third Infantry, U. S. A.





Record of observations made during the month of August, 1891.

ABILENE, TEX.

Date.	8 a. m., seventy-fifth meridian time=6:21 a. m. local time.						8 p. m., seventy-fifth meridian time=6:21 p. m. local time.					
	Cor- rected barom- eter.	Tem- pera- ture.	Rela- tive hu- mid- ity.	Wind.		Pre- cipita- tion.	Cor- rected barom- eter.	Tem- pera- ture.	Rela- tive hu- mid- ity.	Wind.		Pre- cipita- tion.
				Direc- tion.	Veloc- ity.					Direc- tion.	Veloc- ity.	
					<i>Miles.</i>						<i>Miles.</i>	
1	29.90	71	93	0	0	.22	29.90	66.5	97	NW.	19	28
2	30.00	69	95	W.	5	.06	.92	87	41	NW.	3	T.
3	.05	67	98	0	0		.97	86.6	40	S.	4	
4	.04	72	82	SE.	1		.95	90	41	SE.	12	
5	.04	75	66	S.	10		.97	90	34	SE.	18	
6	.06	74	74	SE.	7		.96	90	34	SE.	13	
7	.06	74	74	S.	7		.97	90	41	SE.	10	
8	.06	75	74	S.	9		.94	86	45	SE.	18	
9	.03	78	67	S.	10		.95	82	55	SE.	10	T.
10	.00	72	91	S.	8	.62	.96	77	78	E.	14	
11	.02	75	82	S.	12	T.	30.02	78	71	SE.	8	10
12	.13	71	95	S.	2		.08	78	73	S.	11	
13	.11	68.5	98	S.	2		.00	87	54	SE.	16	
14	.04	71	86	S.	6		29.94	90	54	SE.	12	
15	.02	74	84	S.	12		.93	90	54	SE.	11	
16	.07	74	84	S.	4		.96	90	54	E.	9	
17	.06	75	84	S.	7		.93	90	54	SE.	17	
18	.02	76	85	S.	8		.90	80	72	N.	2	T.
19	29.97	76	87	S.	12	T.	.81	93	41	SE.	12	
20	.90	77	83	S.	12		.78	97	33	S.	12	
21	.92	80	69	SW.	8		.76	97	31	S.	10	
12	30.09	65	100	NE.	6	.26	30.18	67.2	66	N.	12	44
23	.33	56	97	NW.	3		.14	76.5	41	NW.	4	
24	.13	62.6	67	SE.	6		29.89	84	29	SE.	14	
25	29.97	68	48	S.	17		.91	88	30	SE.	12	
26	30.12	66	61	SE.	7		30.04	88	30	SE.	7	
27	.23	64	79	0	0		.09	86	34	E.	10	
28	.14	65	90	E.	5		.01	83	47	E.	7	
29	.06	73	75	S.	6	.04	.00	80	54	SE.	10	
20	.08	72	71	SW.	7	.01	.07	78.6	58	NE.	12	T.
21	.17	69.5	86	N.	4	T.	.14	73.0	78	S.	6	
Mean	30.06	71.1	81.2	S.	6.5	*1.21	29.97	84.5	49.9	SE.	10.8	*.82

EL PASO, TEX.

					<i>Miles.</i>						<i>Miles.</i>	
1	29.80	75	38	E.	12		29.81	83.1	31	E.	24	
2	.93	73.1	49	E.	14		.83	89.9	23	SE.	8	
3	30.02	71.2	40	0	0		.84	92.2	20	E.	9	
4	29.96	73	32	E.	7		.81	93.8	17	SE.	7	
5	.96	72	42	NW.	3	T.	.79	97.7	10	S.	2	
6	.89	74.9	27	SE.	5		.75	94.4	14	SE.	5	
7	.88	72.5	43	SE.	7		.77	91.2	17	SE.	7	
8	.90	74	40	E.	10		.75	91.9	17	E.	7	
9	.90	73.4	46	E.	8		.81	82.0	28	SE.	8	T.
10	.95	67.1	59	SE.	3		.79	89.6	18	SE.	6	
11	.91	72.2	51	W.	10		.84	87.8	25	SE.	8	
12	30.02	73	51	E.	8		.88	88.2	21	SE.	9	
13	.03	70.5	51	0	0		.86	89.6	21	SE.	5	
14	29.98	70.6	46	SE.	4		.82	90.4	18	SE.	6	
15	.91	70.8	45	SE.	7		.77	91.4	16	SE.	5	
16	.91	72	36	SE.	7		.85	85.2	28	SE.	14	
17	.97	65.8	53	SE.	2		.90	75.8	57	NE.	28	.04
18	.98	66.7	75	NE.	4		.80	84.5	37	0	0	T.
19	.90	69	75	N.	3	T.	.73	93.9	18	W.	3	
20	.86	74	22	NW.	12		.78	92.4	18	SE.	5	
21	.88	69.6	42	NE.	7		.75	99.4	7	NW.	6	
22	.96	70	50	NE.	28		.98	77.0	40	SE.	17	
23	30.20	61	60	E.	12		.93	83.0	28	SE.	6	
24	29.94	67.8	35	SE.	8		.71	91.2	18	SW.	4	
25	.77	77.2	32	W.	5		.69	95	6	NW.	3	
26	.90	74.2	34	W.	14		.80	92.8	13	NE.	24	T.
27	30.01	73.2	29	N.	7	.03	.90	90	15	SE.	11	
28	.02	73.3	40	NE.	17		.84	86.7	22	E.	4	
29	29.93	70	53	NE.	23	T.	.95	70	56	NE.	18	T.
30	30.02	67.9	58	NE.	12	.02	.99	69.6	66	NE.	15	T.
31	.09	64.1	79	NE.	10	.04	30.00	73.9	50	SE.	11	T.
Mean	29.95	70.9	46.2	SE.	8.7	*.09	29.83	87.5	25	SE.	9.2	*0.4

*Total.

Record of observations made during the month of August, 1891—Continued.

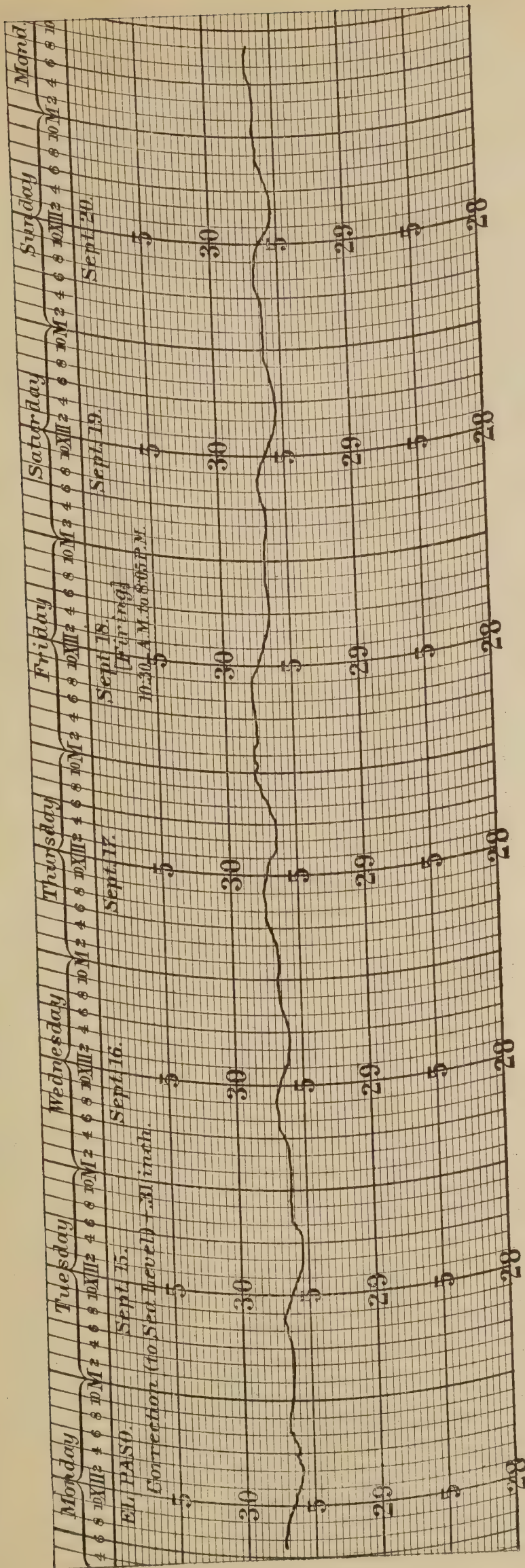
SANTA FÉ, N. MEX.

Date.	8 a. m. seventy-fifth meridian time=5:56 a. m. local time.						3 p. m. seventy-fifth meridian time=5:56 p. m. local time.					
	Cor- rected barom- eter.	Tem- pera- ture.	Rela- tive hu- mid- ity.	Wind.		Pre- cipita- tion.	Cor- rected barom- eter.	Tem- pera- ture.	Rela- tive hu- mid- ity.	Wind.		Pre- cipita- tion.
				Direc- tion.	Ve- locity.					Direc- tion.	Ve- locity.	
					<i>Miles.</i>						<i>Miles.</i>	
1	30.02	60	48	E.	4		29.97	72.8	22	N.	16	
2	.11	55	59	E.	3		30.04	74.8	12	NE.	10	
3	.11	61	44	E.	8		29.97	79	19	NW.	8	
4	.04	64.8	48	E.	4		.96	80	23	NE.	6	
5	.00	64.2	47	E.	5		.98	72	71	SW.	13	
6	.04	63	51	E.	2	T.	30.01	72	42	SW.	18	.01
7	.06	63.5	53	E.	4		.00	73	39	SE.	12	.06
8	.08	58.	46	NE.	5	T.	29.96	78	27	SE.	11	
9	.02	60.5	48	NE.	2	.01	.96	74.5	26	E.	3	
10	.05	55.4	76	NE.	8	.10	30.04	64	65	E.	6	.12
11	.13	57.5	61	NE.	6		.02	78	13	SE.	12	
12	.14	64	51	SE.	6		.06	78	24	S.	6	
13	.14	61.2	49	E.	3		.98	82	18	SW.	7	
14	.05	62.0	50	SE.	3		.94	82.1	18	W.	6	
15	.00	63	42	SE.	3		.91	83	11	S.	12	
16	.04	65.1	39	SE.	6		.95	80	15	SE.	12	
17	.04	63	46	SE.	4		.94	76	25	S.	12	
18	.00	59	65	SE.	4	.02	.88	72.8	39	SE.	6	
19	29.89	57	71	NE.	8	.01	.96	78.2	18	NW.	8	
20	30.00	56.8	45	NE.	13		.96	80	10	N.	13	
21	.00	59	40	NE.	2		.92	82	7	NW.	12	
22	.12	54	70	SE.	2		30.15	65	39	SE.	12	
23	.29	51	62	S.	3		.02	74	23	SW.	6	
24	29.99	57	50	SE.	2		29.83	81	15	N.	6	
25	.87	58.1	32	E.	2		.85	83	16	N.	4	
26	.97	61	31	NE.	4		30.00	76.8	20	SE.	16	
27	30.14	63.2	38	SE.	7		.09	71	34	SE.	4	
28	.18	53.6	82	NE.	8	T.	.10	59	62	SE.	8	.22
29	.19	51	81	SE.	2	T.	.13	56	65	NE.	8	.02
30	.20	51	68	NE.	3	.23	.18	58	67	E.	8	.21
31	.27	47	86	E	3	.01	.12	71	30	W.	4	
Mean	30.07	58.7	54.2	{ NE. SE. E. }	4.5	*.38	30.00	74.4	29.5	SE.	9.2	*.64

CORPUS CHRISTI AND SAN ANTONIO, TEX.

1	29.92	82	88	S.	11		29.91	78.5	73	SE.	9	
2	.99	80	92	NW.	4		.95	71	86	0	0	.50
3	30.02	75	100	S.	12	2.40	30.01	73.2	78	N.	4	
4	.04	79	94	S.	2		.05	74.3	84	SE.	2	.08
5	.11	78.8	83	S.	2		.13	73.5	74	NW.	2	
6	.12	81	88	SE.	2		.14	75.5	76	SE.	2	
7	.10	81	88	S.	6		.13	77	59	SE.	4	
8	.08	80	83	SE.	4		.10	75	84	0	0	
9	.06	81.5	86	SE.	9		.08	76	80	SE.	2	
10	.04	80	87	SE.	9		.08	76	82	0	0	
11	.06	80.5	90	SE.	6		.08	78	77	SE.	5	
12	.10	80	92	N.	3		.12	78.2	81	0	0	
13	.08	79	91	N.	3		.10	78	71	SW.	1	
14	.03	79	91	N.	5		.06	77	71	0	0	
15	.01	81	88	W.	3		.05	76.5	74	0	0	
16	.03	80	92	0	0	.19	.08	76.5	76	E.	4	
17	.04	81.2	91	SE.	2	.04	.09	78	71	SE.	4	
18	.04	82.5	86	SE.	2		.06	78	77	SE.	1	
19	29.98	82	84	SE.	6		.02	78	75	SE.	2	
20	.99	83	84	SE.	4		29.99	78	75	SE.	3	
21	.96	82	84	SE.	4		.98	78.1	77	SE.	3	
22	.94	82	84	SE.	9		.97	77.5	78	SE.	5	
23	30.12	68.5	83	N.	12	.02	30.19	68	60	N.	9	.47
24	.10	68	67	N.	4		.14	61.5	66	NE.	7	
25	.04	77	59	SE.	5		.07	61	71	0	0	
26	.11	73.5	80	N.	4		.17	66	75	0	0	
27	.14	71	86	NW.	6		.20	66.5	78	NE.	5	
28	.10	73	84	N.	8		.13	69.2	67	NE.	6	
29	.05	76	87	W.	4		.09	70.2	73	N.	3	
30	.05	78	87	SW.	2		.10	74.5	70	0	0	
31	.10	77	87	N.	3		.14	72	75	0	0	
Mean	30.05	78.5	86	SE.	5	*2.65	30.08	74	74.6	SE.	2.7	*1.05

* Total.



EXPERIMENTS IN PRODUCTION OF RAINFALL.

Record of observations during the month of September, 1891.

EL PASO, TEX.

Date.	8 a. m., seventy-fifth meridian time=5:54 a. m. local time.						8 p. m., seventy-fifth meridian time=5:54 p. m. local time.					
	Cor- rected barom- eter.	Tem- pera- ture.	Rela- tive hu- mid- ity.	Wind.		Pre- cipita- tion.	Cor- rected barom- eter.	Tem- pera- ture.	Rela- tive hu- mid- ity.	Wind.		Pre- cipita- tion.
				Direc- tion.	Veloc- ity.					Direc- tion.	Veloc- ity.	
					Miles.						Miles.	
1	30.08	62.9	82	E.	5		29.91	81.9	36	SE.	3	
2	.00	60.9	73	0	0		30.00	72.2	59	SE.	7	.07
3	.15	63.2	73	E.	14		.03	77	38	SE.	7	
4	.12	59.2	71	SE.	4		29.96	82.5	24	0	0	
5	.06	60.0	57	SE.	1		30.01	86.3	13	SE.	4	
6	.15	68.3	23	SE.	9		.04	84.7	14	SE.	5	
7	.10	63.3	37	SE.	1		29.89	90.7	12	W.	5	
8	29.90	73.1	22	NW.	12		.87	85.8	24	NE.	19	.01
9	30.03	71.0	34	E.	13		.90	87.5	21	SE.	4	
10	.00	69.0	59	N.	4	.03	.83	89.1	21	NW.	7	
11	29.88	72.5	40	NW.	7		.77	93.1	14	NW.	9	
12	.90	76.4	33	NW.	12		.83	92.2	15	W.	7	
13	.95	70.3	50	W.	2		.92	82	31	SE.	17	T.
14	.99	71.0	54	NE.	4	.02	.90	81.3	35	SE.	4	T.
15	.93	66.6	60	E.	4	T.	.80	89.9	18	SE.	1	
16	.91	70.7	39	N.	10		.86	87.1	10	NW.	5	
17	30.00	73.3	28	0	0	T.	.91	83	26	E.	2	
18	30.08	65.0	89	0	0	.07	.89	84	24	SW.	7	
19	29.98	61.0	73	SE.	4		.86	85.7	15	SE.	4	
20	.94	64.8	61	SE.	4		.86	81.4	31	SE.	13	
21	.97	69.3	54	E.	10		.87	83	31	SE.	6	
22	.98	70.1	35	SE.	10		.78	84	25	SE.	7	
23	.85	67.9	54	SE.	3	.02	.69	80.9	33	S.	6	
24	.79	65.0	64	SE.	2		.67	83.5	22	SW.	4	
25	.87	65.4	74	E.	8	.01	.81	75	54	SE.	12	T.
26	.90	63.7	86	E.	8		.77	82.6	7	W.	10	
27	.92	56.0	34	NW.	2		.83	80	12	NE.	5	
28	.96	57.1	44	N.	4		.92	81.8	23	E.	20	
29	30.03	66.0	58	E.	16		.84	76	41	SE.	5	
30	29.78	63.7	76	E.	8		.59	77.9	43	S.	7	T.
Mean	29.97	66.2	54.3	E., SE.	6	*.15	29.86	83.4	25.7	SE.	7.1	*.08

CORPUS CHRISTI, TEX.

1	30.08	76.	87	W.	4		30.00	83.5	76	E.	21	
2	.01	80.5	84	SE.	3		29.93	82	76	SE.	7	
3	.04	77.2	91	N.	12	T.	30.02	81	72	E.	8	
4	.13	73.	73	N.	16		.07	78.5	60	E.	17	
5	.13	74.	78	NE.	10		.09	80	54	E.	13	
6	.18	69.5	76	N.	6		.10	81	58	SE.	12	
7	.15	71.3	58	N.	6		.04	81	65	SE.	13	
8	.08	67.5	94	SW.	8		.04	81	61	E.	12	
9	.11	73.	82	SW.	4		.08	81	70	E.	15	
10	.10	73.8	83	W.	4		.00	81.6	76	SE.	12	
11	.02	81.	80	SE.	4		29.97	82	72	SE.	17	
12	.02	81.	72	SE.	9		.98	82	65	SE.	14	
13	.04	71.	91	SW.	4		.95	84	59	SE.	14	
14	.03	72.	86	S.	14	T.	.97	82.1	92	E.	12	.10
15	.05	74.	88	SE.	3	.40	30.02	81	80	SE.	15	.10
16	.11	80.9	90	SE.	7	.02	.07	82.1	86	E.	24	
17	.13	82.	88	SE.	10		.10	83	84	SE.	14	
18	.15	82.1	79	SE.	12		.06	82	80	E.	23	
19	.05	81.	82	E.	11	T.	.03	82.1	74	E.	19	.10
20	.07	75.	91	N.	10		29.97	81.5	63	SW.	6	
21	.03	75.	84	SW.	6		.98	80	75	E.	19	.08
22	.04	75.	91	NE.	11	.02	30.00	81	70	E.	19	.22
23	29.98	73.8	96	N.	6	.04	29.88	80.9	78	E.	15	
24	.88	76.	91	NE.	6	T.	.87	78.5	85	NE.	16	.06
25	.90	73.	96	E.	6	.66	.93	81	80	NE.	24	1.37
26	.91	75.	91	N.	17	.01	.83	80	92	NE.	23	.16
27	.89	79.5	89	SE.	12	.09	.88	81.5	84	SE.	19	T.
28	.93	81.	82	SE.	12	T.	.96	81.5	86	E.	15	.01
29	30.03	79.6	85	SE.	15	.83	.97	81	80	NE.	9	.21
30	29.96	80.1	85	SE.	12	.03	.89	82.1	82	SE.	19	.14
Mean	30.04	76.1	84.8	SE.	8.7	*2.10	29.99	81.3	74.5	E.	15.5	*2.55

* Total.

Record of observations during the month of September, 1891—Continued.

SAN ANTONIO, TEX.

Date.	8 a. m., seventy-fifth meridian time=6:30 a. m. local time.						8 p. m., seventy-fifth meridian time=6:30 p. m. local time.					
	Cor- rected barom- eter.	Tem- pera- ture.	Rela- tive hu- mid- ity.	Wind.		Pre- cipita- tion.	Cor- rected barom- eter.	Tem- pera- ture.	Rela- tive hu- mid- ity.	Wind.		Pre- cipita- tion.
				Direc- tion.	Veloc- ity.					Direc- tion.	Veloc- ity.	
1	30.13	73	69	NE.	<i>Miles.</i> 5		29.98	88	43	SE.	5	
2	.06	71.3	79	NE.	5		.96	84.1	51	E.	9	
3	.10	74.2	66	NE.	10		30.07	82	45	NE.	9	
4	.19	59.2	70	N.	7		.09	80.5	34	SE.	6	
5	.17	61.3	66	N.	5		.09	84.5	34	SE.	3	
6	.19	64.5	65	NW.	3		.08	85.5	32	NE.	8	
7	.16	68	63	N.	6		.02	86.5	34	SE.	4	
8	.10	69	70	W.	2		.01	84	29	SE.	8	
9	.15	68.5	66	0	0		.06	84	41	E.	5	
10	.10	68	71	NW.	3		29.96	87	34	SE.	5	
11	.06	74	68	SE.	3		.93	88.5	38	SE.	8	
12	.06	73	69	0	0		.96	89	33	SE.	8	
13	.06	69.5	68	NW.	3		.98	88	27	NE.	6	
14	.07	71	66	NE.	6		30.01	71.5	82	N.	6	.21
15	.07	71	81	E.	7	.06	.06	73	78	SE.	4	1.06
16	.15	74	82	SE.	3	.02	.08	74.8	72	E.	10	
17	.18	75.5	78	SE.	5		.10	82.5	62	SE.	10	
18	.19	74	80	E.	3		.09	76	74	E.	4	
19	.12	72.2	84	NE.	3	.71	.04	82	60	SE.	4	.03
20	.11	67	73	N.	4		.02	82	58	0	0	
21	.08	68.7	72	N.	8		29.99	82	43	NE.	7	
22	.09	70	79	NE.	8		30.04	74.5	78	E.	7	.04
23	.05	71	79	E.	8		29.91	78.6	66	E.	8	
24	29.93	71	81	E.	10	.15	.91	74.4	78	E.	12	
25	30.02	71	95	E.	9	.05	30.00	73	91	E.	5	.40
26	.00	70	83	NE.	9		29.89	81.5	50	NE.	8	
27	29.93	73.9	84	E.	7	T.	.92	77.5	83	E.	6	.16
28	30.00	74.6	84	E.	3	.03	30.00	80.5	61	SE.	4	
29	.13	68.5	88	NE.	12	.54	.03	76	66	NE.	7	T.
30	.01	72	95	E.	4	.02	29.90	75.2	87	SE.	4	.12
Mean...	30.09	70.3	75.8	NE. E.	5.4	*1.58	30.01	80.9	55.5	SE.	6.3	*2.02

CORPUS CHRISTI, TEX.

1	29.90	71	84	SE.	13	T.	29.88	82.5	86	SE.	19	
2	.92	81.5	82	SE.	18	.02	.90	82	84	SE.	24	
3	.90	81.5	80	E.	19	.10	.90	81	80	SE.	12	T.
4	.91	75	95	NE.	9		.94	75	74	N.	18	
5	30.01	65.5	61	N.	12		.92	74.8	68	N.	10	
6	29.95	67.6	83	N.	13		30.02	68.3	81	N.	19	
7	30.14	64.4	71	N.	17		.11	67	45	N.	11	
8	.22	54	70	N.	11		.15	71.1	56	N.	4	
9	.21	61.5	71	NW.	10		.16	71.5	50	N.	11	
10	.22	54	76	N.	11		.14	67	49	E.	11	
11	.17	58	78	E.	4		.13	72	69	E.	10	
12	.16	66	85	SE.	4		.11	74	70	E.	10	
13	.10	66.5	90	0	0		.07	74.4	86	E.	12	
14	.13	66.5	95	S.	6		.10	74.9	83	SE.	11	
15	.16	70	95	NW.	3		.11	75.8	81	E.	15	
16	.12	70.1	84	S.	5		.08	76	82	E.	13	
17	.13	71.5	84	SW.	5		.15	77	78	SE.	11	
18	.32	70	77	N.	17		.34	71	45	N.	9	
19	.40	56	57	N.	9		.30	70.9	54	SE.	9	
20	.27	55.5	62	W.	12		.27	72	65	SE.	9	
21	.30	61	87	W.	5		.26	73	69	SE.	11	
22	.31	63	93	NW.	4		.26	72	65	SE.	8	
23	.30	62	89	SW.	9		.25	73	82	SE.	11	
24	.22	67	76	SE.	6		.14	75	72	SE.	13	
25	.14	68.5	85	S.	5		.15	74.8	86	SE.	15	
26	.21	71	91	SE.	4		.23	75	80	SE.	11	
27	.30	68.1	95	N.	3		.27	74.9	83	SE.	6	
28	.33	66.5	92	N.	11		.27	74.5	76	E.	18	
29	.27	72.2	65	E.	13		.23	74.5	66	E.	19	
30	.21	70.5	79	SE.	4		.17	75.2	82	SE.	12	
31	.19	70	86	N.	2		.16	76	82	SE.	15	
Mean...	30.16	67	81.2	N.	8.5	*.12	30.13	74.1	71.9	SE.	12.5	T.

*Total.

EXPERIMENTS IN PRODUCTION OF RAINFALL.

Record of observations during the month of October, 1891.

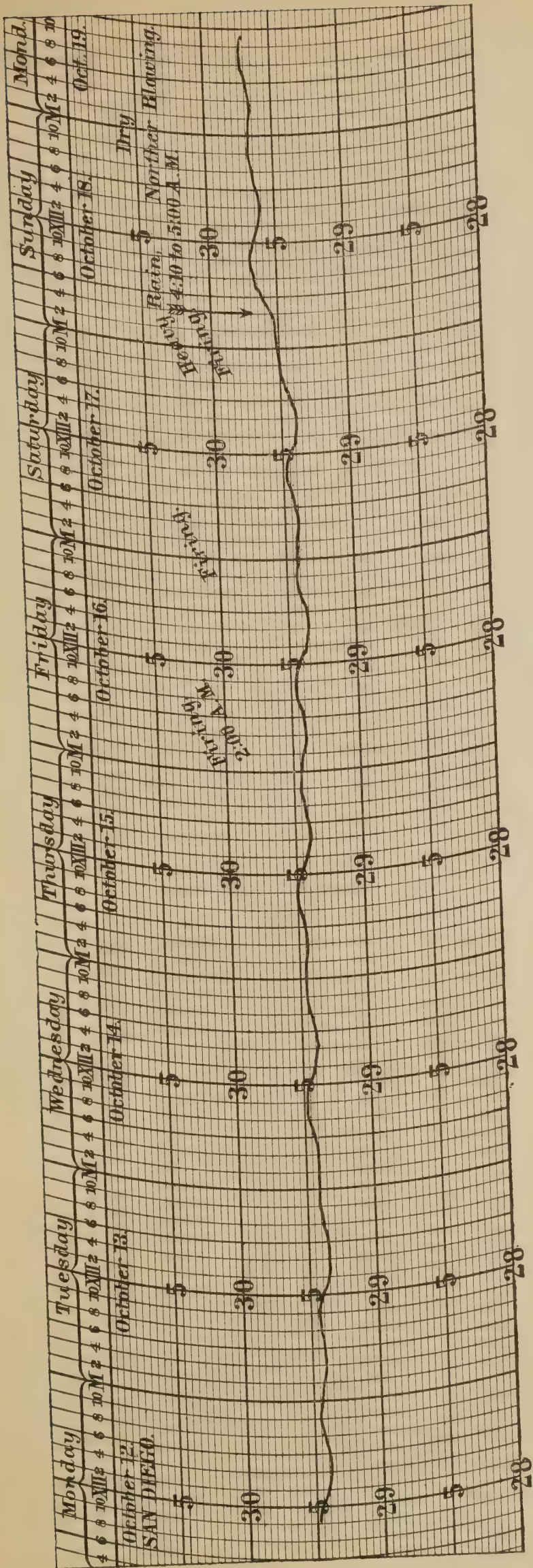
SAN ANTONIO, TEX.

Date.	8 a. m., seventy-fifth meridian time=6:26 a. m. local time.						8 p. m., seventy-fifth meridian time=6:26 p. m. local time.					
	Cor- rected barom- eter.	Tem- pera- ture.	Rela- tive hu- mid- ity.	Wind.		Pre- cipita- tion.	Cor- rected barom- eter.	Tem- pera- ture.	Rela- tive hu- mid- ity.	Wind.		Pre- cipita- tion.
				Direc- tion.	Veloc- ity.					Direc- tion.	Veloc- ity.	
					Miles.						Miles.	
1	29.92	74.3	88	SE.	6		29.87	79.7	66	SE.	8	
2	.95	75	87	SE.	6	.03	.92	78.6	73	SE.	8	.14
3	.94	74	86	SE.	4		.92	75	84	0	0	.22
4	30.02	65.5	70	N.	9	.02	30.06	58.5	72	N.	16	
5	.10	61	58	N.	6		29.97	69.3	55	N.	6	
6	.01	59	67	NE.	7		30.10	65.5	59	N.	9	
7	.26	54	59	N.	12		.16	63.5	36	N.	6	
8	.26	50.1	64	N.	6		.16	72	42	E.	4	
9	.26	57.5	66	NE.	9		.21	69.5	50	N.	5	
10	.28	49.5	64	N.	4		.15	67	51	SE.	3	
11	.22	47.1	62	N.	4		.16	67	45	SE.	7	
12	.21	54	70	NE.	3		.10	73.2	44	SE.	5	
13	.13	58	75	0	0		.05	75	42	SE.	4	
14	.19	61.3	63	N.	6		.11	73.7	48	SE.	4	
15	.18	64	70	E.	4		.08	77.3	45	SE.	5	
16	.14	64	72	NE.	3		.06	76.2	46	SE.	7	
17	.14	62.2	100	0	0		.13	78	46	SE.	4	
18	.40	65	31	N.	12	.19	.39	64	38	N.	6	
19	.46	50.5	46	N.	5		.31	67	37	SE.	6	
20	.33	49.5	64	NW.	4		.28	71.5	32	SE.	4	
21	.32	53	69	N.	4		.26	75	34	SE.	3	
22	.35	57.4	66	N.	5		.25	74.9	39	SE.	5	
23	.32	58.2	61	NW.	5		.23	74.6	40	S.	3	
24	.25	58	100	0	0		.11	74	41	S.	5	
25	.19	60	78	N.	5		.15	74.1	43	S.	4	
26	.24	64.8	87	0	0		.22	75.7	45	SE.	3	
27	.33	62	79	NE.	3		.26	77.5	40	SE.	4	
28	.34	58.4	67	N.	7		.27	75.2	40	E.	7	
29	.32	59.5	60	NE.	4		.22	71.7	55	SE.	4	
30	.25	58	83	E.	5		.16	74	45	SE.	4	
31	.22	65.5	85	E.	2		.16	75.5	50	SE.	5	
Mean	30.21	59.7	70.9	N.	4.8	*.24	30.14	72.4	47.8	SE.	5.3	*.36

RIO GRANDE CITY, TEX.

1	29.84	77.5	85	E.	8		29.79	84.9	68	SE.	10	
2	.86	77.2	91	E.	4		.83	78.9	87	E.	4	.36
3	.85	74.8	93	NE.	5	.12	.83	79.6	88	E.	7	.03
4	.89	72.7	95	NE.	4	.01	.93	71.1	90	NW.	8	.76
5	30.02	64.1	76	NW.	9	.01	.88	75.8	60	NW.	2	
6	29.93	64.5	92	NW.	2		.94	80	61	N.	9	
7	30.13	64	64	NW.	9		30.07	70.2	53	N.	5	
8	.20	52.2	80	N.	1		.12	71.2	40	N.	3	
9	.19	52.2	86	N.	1		.12	74.5	40	NE.	9	
10	.20	53.2	83	NE.	5		.08	69.2	43	NE.	6	
11	.13	52.1	89	NE.	4		.05	71.5	50	E.	4	
12	.12	60	81	NE.	3		.04	75	53	E.	3	
13	.06	60.4	88	0	0		.01	76.8	53	E.	4	
14	.12	60	91	NE.	3		.06	75.6	63	E.	4	
15	.09	66.5	92	E.	3		.04	77.8	57	SE.	4	
16	.06	66.1	89	SE.	3		.02	78.8	51	SE.	6	
17	.08	66.5	88	0	0		.08	80.9	50	E.	6	
18	.27	63.1	89	N.	4		.32	71.3	40	W.	9	
19	.39	49	80	W.	2		.28	67.7	38	NE.	3	
20	.32	44.3	70	NW.	5		.21	68.1	50	SE.	4	
21	.26	51	88	N.	4		.20	71.8	49	SE.	4	
22	.28	52.9	86	N.	2		.21	72.5	52	E.	2	
23	.28	54.7	85	0	0		.19	71	52	E.	4	
24	.18	58	90	NE.	4		.06	75.2	54	E.	6	
25	.08	62.5	90	NE.	4		.07	77	50	NE.	5	
26	.16	63.5	93	NE.	3		.18	73.8	70	SE.	10	
27	.27	64.6	87	N.	3		.23	75.2	55	E.	2	
28	.29	57.6	88	N.	4		.20	75	55	E.	6	
29	.24	59.7	92	NE.	4		.14	76.5	54	NE.	9	
30	.16	65	92	E.	2		.10	75	55	E.	4	
31	.12	67.2	92	E.	4		.07	78.5	42	E.	5	
Mean	30.13	60.9	86.6	NE.	3.5	*.14	30.08	74.9	55.6	E.	5.4	*1.15

*Total



EXPERIMENTS IN PRODUCTION OF RAINFALL.

Record of observations during the month of November, 1891.

CORPUS CHRISTI, TEX.

Date.	8 a. m., seventy-fifth meridian time=6:30 a. m. local time.						8 p. m., seventy-fifth meridian time=6:30 p. m. local time.					
	Cor- rected barom- eter.	Tem- pera- ture.	Rela- tive hu- mid- ity.	Wind.		Pre- cipita- tion.	Cor- rected barom- eter.	Tem- pera- ture.	Rela- tive hu- mid- ity.	Wind.		Pre- cipita- tion.
				Direc- tion.	Veloc- ity.					Direc- tion.	Veloc- ity.	
					<i>Miles.</i>						<i>Miles.</i>	
1	30.154	68.5	95	W.	2	1.59	30.157	76.5	74	E.	13	0
2	30.192	71.0	79	N.	10	.01	30.199	74.0	82	SE.	19	.30
3	30.239	75.5	66	E.	15	.02	30.225	76.0	70	E.	14	0
4	30.239	72.4	82	SE.	3	0	30.154	75.0	78	SE.	10	0
5	30.134	64.0	94	W.	7	0	30.031	74.5	82	SE.	13	0
6	30.020	70.0	90	SE.	4	0	29.930	75.2	86	SE.	15	0
7	29.939	72.0	93	SE.	5	0	29.822	76.0	82	SE.	13	0
8	29.754	73.5	91	SE.	12	0	29.641	78.0	81	S.	19	0
9	30.027	55.0	59	NW.	24	.50	30.073	59.0	49	W.	10	0
10	30.033	45.4	64	SW.	12	0	29.931	65.0	61	S.	10	0
11	29.966	61.5	81	S.	9	0	29.980	73.0	80	SE.	11	0
12	30.263	57.9	56	N.	17	T.	30.210	67.0	53	N.	6	0
13	30.211	61.0	84	N.	6	0	30.157	71.0	81	SE.	12	T.
14	30.165	71.0	81	SE.	12	0	30.123	72.1	83	SE.	13	T.
15	30.067	70.5	88	SE.	8	0	29.995	74.0	86	SE.	14	0
16	29.998	72.0	91	SE.	3	0	30.006	76.0	82	SE.	12	T.
17	30.511	43.0	55	N.	30	.08	30.581	49.5	34	N.	12	0
18	30.669	38.0	57	N.	19	0	30.422	55.0	79	NE.	18	6
19	30.276	54.0	76	N.	7	0	30.166	64.0	87	NE.	3	T.
20	30.109	66.0	90	SE.	3	0	30.004	68.0	86	SE.	8	0
21	29.934	70.3	93	SE.	7	.01	29.797	73.8	83	S.	9	.01
22	29.870	59.0	94	SW.	7	0	30.134	56.8	31	N.	7	0
23	30.195	48.0	47	N.	11	0	30.094	56.5	60	SE.	5	0
24	30.071	54.0	64	NE.	17	0	30.022	59.0	88	N.	9	T.
25	30.064	51.0	93	W.	12	.01	29.952	61.5	54	NW.	2	0
26	29.954	48.0	63	SW.	6	0	30.029	62.5	69	S.	4	0
27	30.014	52.0	84	SW.	5	0	28.865	70.0	75	S.	18	0
28	29.943	62.6	97	S.	5	0	30.195	65.7	42	N.	21	0
29	30.537	42.5	50	N.	14	0	30.491	55.5	46	NE.	12	0
30	30.455	47.0	72	N.	18	0	30.309	58.0	70	E.	12	0
Mean	30.135	59.9	77.6	N., SE.	10.3	.074	30.090	67.3	70.5	SE.	11.5	.010

SAN ANTONIO, TEX.

1	30.205	66.5	82	0	0		30.154	74.0	50	S. E.	5	
2	30.230	63.2	97	N. E.	5		30.206	74.3	52	E.	5	
3	30.287	62.5	87	N. E.	5		30.228	73.5	46	S. E.	4	
4	30.260	61.7	100	E.	2		30.146	74.0	47	S. E.	5	
5	30.153	61.0	87	W.	4		30.009	76.0	38	S. E.	4	
6	30.041	61.0	100	0	0		29.886	76.5	48	S. E.	8	
7	29.890	68.0	78	S. E.	4		29.759	79.0	43	S.	5	
8	29.739	70.7	86	0	0		29.739	72.7	23	N. W.	17	
9	30.033	50.0	52	N. W.	21		30.096	58.0	18	N. W.	9	
10	30.055	39.5	36	W.	5		29.911	67.5	26	S.	5	
11	29.989	50.0	52	0	0		30.029	73.0	39	N.	18	
12	30.357	47.0	55	N.	17		30.248	57.5	32	N. E.	8	
13	30.264	55.0	51	N.	5		30.156	69.5	72	E.	15	
14	30.204	61.0	78	S. E.	2		30.106	74.0	66	S. E.	15	
15	30.091	68.5	81	S. E.	9		29.986	74.0	72	S. E.	11	
16	30.008	70.0	81	S. E.	4		30.075	72.5	67	N.	24	T.
17	30.630	34.0	58	N.	19	0.07	30.679	43.0	34	N.	9	
18	30.738	34.0	35	N.	9		30.510	43.0	51	0	0	
19	30.351	45.0	71	E.	5	0.02	30.227	56.0	55	E.	6	
20	30.136	59.0	100	S. E.	3	0.22	30.003	70.3	77	S. E.	3	0.03
21	29.978	64.5	97	S. E.	4	0.04	29.842	60.0	94	0	0	0.54
22	30.087	47.2	55	N. W.	22		30.153	52.2	51	N. W.	3	
23	30.240	34.3	44	0	0		30.135	55.5	44	S. E.	5	
24	30.154	38.0	66	N.	7		30.074	59.5	48	E.	4	
25	30.088	44.8	64	N. W.	7		29.969	54.5	50	S. E.	6	
26	30.016	47.2	59	N. W.	6		30.059	63.5	38	N. E.	5	
27	30.048	45.1	64	N. W.	4		29.878	71.5	29	S.	5	
28	30.006	51.5	66	N.	6		30.357	57.1	31	N.	13	
29	30.599	38.0	46	N. E.	9		30.520	48.5	50	N. E.	7	
30	30.518	35.0	59	N. E.	4		30.321	53.0	41	S. E.	7	
Mean	30.182	52.4	69.6	N., SE.	6.3	0.12	30.115	61.5	47.7	S. E.	7.7	.019

STATEMENT OF MR. FAIRCHILD.

The expedition has completed its work for the season, and the question is asked, "Have the experiments been successful?" As a member of the expedition, I am convinced that the experiments have been entirely successful, and furthermore, that the scheme is practicable; the cost being very small as compared with the benefit gained. A tax of a few cents an acre would cover the expense of operations extending over the entire dry season.

A word as to the theories of "rainmaking" in answer to the objection which many scientists have raised, that the force of a heavy explosion is momentary in its effect, and hence, if the concussions did cause the rain to fall, it should come at once; it is not claimed that the explosions themselves will cause rain to fall from a *clear* sky, but that they will start a *storm center*, and then in the natural course of things the intermingling of the currents, and other disturbances will progress, until rain will fall.

On the other hand, when the conditions are favorable and clouds are present, as they are in many portions of Texas during many days of the driest seasons, rain can be made to fall in greater or less quantity, within a few seconds after the explosion, as we demonstrated time and again during the experiments.

At El Paso, we began work at about 10 a. m., exploding charges of dynamite and rackarock powder at intervals of about two minutes until 8:03 p. m., with explosions of the large oxy-hydrogen balloons, containing from 600 to 1,000 cubic feet of this powerful explosive, every forty-five minutes. In the evening, heavy clouds gathered but passed off to the southeast. The next morning, September 19, it was learned that the rain had fallen in torrents all along the valley of the Rio Grande. The Weather Bureau reports, for the section of country covered by the rain on that day, had been for extreme dry weather with rising barometer.

From El Paso the party went to Corpus Christi, by way of San Antonio, intending to operate there, but as it commenced raining on the day of our arrival and continued for nearly a week, we went back into the country, 50 miles out of the rain belt, to San Diego. Here Mr. Ellis, wishing, as this was to be the last experiment, to have it as complete and positive as possible, waited nearly three weeks until the weather had settled in for a long drought.

On Thursday night, October 15, the line was arranged. Directly east of the camp was placed a 12-pound cannon. Next the 21-pound mortar batteries for throwing the bombs into the air to the height of 500 feet or more. Beyond these were the dynamite and rackarock stations, extending nearly three-quarters of a mile down the road toward San Diego. The balloons were filled and started, with time fuses, from an open space west of the camp. A light cannonading was carried on Thursday and Friday nights, but the final bombardment of the heavens on Saturday night was on a much larger scale than we had ever attempted before. The sky was cloudless and the weather predictions were most decidedly against rain, but on Sunday morning the rain fell heavily for an hour, our rain-gauge showing an inch and a half of precipitation.

The almost unanimous decision of all responsible persons who have witnessed our work is that it has been a great success, and that without a doubt it will soon be a thing of the past for the Texas cotton-grower to lose two-thirds of his crop for lack of rain at the right time.

EUGENE FAIRCHILD.

CHICAGO, ILL., *November 1, 1891.*

 OPINIONS OF SPECTATORS.

[Extract from a letter from the Delamer Ranch, of San Diego, Tex.]

SAN DIEGO, DUVAL COUNTY, TEX., *November 14, 1891.*

I was present at the experiment on the night of the 17th of October, and on the following morning drove out to the camp to offer you my congratulations, but finding you asleep, did not disturb you.

You are aware that I was very much interested in the object of your visit here. In fact I was one of the first to move in the matter of bringing you to San Diego, for which purpose I went to some expense.

It affords me the greatest pleasure to say that I am satisfied with the result. From what I saw and from what I heard from those who watched throughout the night, I am of the opinion that the rain which fell on the morning of the 18th, was produced by the explosions; that the clouds which gave the rain, formed over this section from a clear sky, and were not carried from afar by the "norther;"

and that had the "norther" not come just at that hour, we would have had a much better rain over this locality.

I will further state that I spoke to several parties on the morning of the 18th, and, without exception, they all attribute the rain to the explosions.

For my part I think the greatest object of the test has been attained, viz: the demonstration that rain, much or little, can be drawn from the sky. One single drop so drawn bears an incalculable importance. Further experiments will teach us how to bring it in greater quantity and the most economical means of doing so.

Very truly yours,

H. J. DELAMER.

P. S.—I would suggest that you write to Mr. R. J. Kleberg, Santa Gertrudes or Collins post-office, Neuces County, Tex., who was the largest subscriber to the "rain" fund, and who represents the largest landed interests in the Southwest. Mr. Kleberg is a gentleman of enlightenment, experience, and sound sense, whose word carries the greatest weight. I think you will find he is pleased with the result.

H. J. D.

[Extracts from letters written by Dr. Lincoln B. Wright, of San Diego.]

SAN DIEGO, TEX., *October 20, 1891.*

* * * Your experiments in rain-making were, in my opinion, a decided success. I feel safe in saying that you evidently produced rain, or, to be more explicit, that rain would not have fallen without the effects produced by your experiments. I have great confidence in the undertaking, and shall watch with interest your future operations. * * *

Yours, very respectfully,

L. B. WRIGHT, M. D.

SAN DIEGO, TEX., *November 13, 1891.*

* * * My brother, the colonel, saw Mr. Kleberg, of the King Ranch, the other day and had a long talk with him about the experiments.

Mr. Kleberg was at the ranch, and in company with several other gentlemen, watched the experiments throughout the night. To say that he is highly pleased with the experiment and that he is thoroughly convinced of its success is to put it mildly; he is enthusiastic and does not regret a dollar that he spent; he only wishes that he had spent more. * * *

Yours truly,

L. B. WRIGHT, M. D.

Mr. Kleberg, to whom Dr. Wright refers, is the manager and principal proprietor of the 1,000,000-acre King Ranch. The ranch subscribed \$1,000 for use in making the experiments, the entire amount of which was not used, however. Mr. Kleberg visited Midland, Tex., in August, immediately after the last experiment at that point, and fully satisfied himself of its success before offering to contribute toward an experiment at San Diego.

The following is from Messrs. F. Gueydan & Co., the principal mercantile and banking house of Southern Texas, consisting of F. Gueydan, C. Tiblier, and George Bodet, the latter of whom is also postmaster of San Diego and treasurer of Duval County. The firm paid a part of the expenses of the experiments at that point:

SAN DIEGO, TEX., *October 20, 1891.*

To whom it may concern:

It gives us great pleasure to testify our high esteem for the manner in which the experiments have been made at this point for the purpose of producing rain.

We can say, without doubt, that the rain which fell at this place on the morning of the 18th, was due entirely to the heavy explosions caused by the Government expedition; that, during their experiments, they have worked hard to obtain the result which we so highly appreciate, and which has been of great benefit to the surrounding country.

We extend our heartfelt thanks and gratitude to each and every member of the expedition.

Respectfully,

F. GUEYDAN & CO.

[Letter from Dr. William Taylor, correspondent of the British Museum and Smithsonian Institution.]

Considering the dry day and night previous to the rainfall at 4 o'clock on Sunday morning, October 18, and the rising barometer and the appearance of a dry norther, I firmly believe that the rain was produced by the explosions made by the Government expenditure, at San Diego. I consider the experiments highly successful, and sincerely hope that further experiments may be tried in this region.

WM. TAYLOR, M. D.

SAN DIEGO, TEX., *October 20, 1891.*

[Letter from Judge James O. Luby, of Duval County, Tex.]

SAN DIEGO, TEX., *October 21, 1891.*

I congratulate you on the success of your experiments at this place.

If your operations of the night of the 17th did not produce the rain in our county on the morning of the 18th instant, it was one of the strangest coincidences I have ever witnessed. The previous desultory explosions unaccompanied or followed by copious showers caused many to be skeptical of the final results; your choosing the night of the 17th, on a rising barometer and an expectant dry norther, made me think you courted failure in the face of a frowning world, as the conditions were more unfavorable than at any time during your stay here. I became interested and hied me to Camp Powers, to witness the final *coup de main*. The smoking batteries and airy balloons were in strange contrast with the clear sky. I was the only person on the ground, out of the hundreds present, that carried an umbrella. I suppose you didn't notice it, as you were busy at the balloons. My reason for carrying it was that I don't care to trifle with science.

After witnessing the heavy cannonading for awhile and seeing no perceptible change in the sky, I feared that Prof. Newcomb's yellow-legged pollywogs would not be afforded an opportunity to disport themselves in water produced by your efforts.

On my return from Camp Powers I watched the forming of clouds with interest. I saw them form from what appeared to be thin air, and banking up in the northwest.

On the explosion of one of the balloons at 2:30 a. m., I was at the lower San Diego bridge, which, as you are aware, is a parabolic iron truss, with a span of 153 feet. I went there out of curiosity to note the effects of the balloon explosions.

The bridge is over $2\frac{1}{2}$ miles from the camp, and the structure rattled and vibrated with great force. I thought, that if the explosions could so visibly affect a solid, well-braced structure at such a distance, that nature, being so constantly shook up from her dewy slumbers, would drop a tear or two in response to the efforts of the rainmakers.

What was my surprise, after retiring for the night, to hear the patter on the shingles; I then knew that, in the language of the festive cowboy, you had "got a cinch on Old Pluvius," and that the "Powers" that be, got there with the limpid *aqua pura*.

Wishing you future success, I remain
Yours truly,

JAMES O. LUBY.

[Letter from Hon. G. W. Fulton, who was present during the operations at El Paso and subscribed \$300 toward the San Diego experiments.]

GREGORY, SAN PATRICIO COUNTY, TEX.,
November 20, 1891.

I have much pleasure in expressing to you my firm conviction that the San Diego experiment was a success, and I should have done so much earlier had I known where to reach you. I had promised myself the pleasure of witnessing it, and very much regret that pressing business called me to Victoria while the experiment was in progress. Your telegram announcing the beginning of operations only reached me Saturday afternoon, at Beeville, on my return from Victoria. At that time I was much discouraged, for I never saw less appearance of rain indications. I remarked to some friends that I was afraid the experiment was a flat failure, and on the Monday morning following, when informed by Mr. Driscoll that a half inch of rain had actually fallen at San Diego and over a wide area contiguous to that point, I was much surprised, and gratified correspond-

ingly. There were many people who attributed the rainfall to the intermingling of the cooler north wind, which arose Sunday morning, with the warmer *moist* air, losing sight of several important facts. First, if I am correctly informed, the rainfall was before the norther and ceased after the norther arose; second, the air was *not moist*, as proven by the hygrometric readings at the time; and last, but not least, there was no rain at all immediately on the coast, where, if there was any difference at all, there must have been much more moisture in the air than at San Diego.

Considering these facts, I am forced to the conclusion that the rainfall was the direct result of the explosions; and I further believe that if it had not been for the norther, the result would have been convincing to the most skeptical.

Always a believer in the theory that rain can be produced by concussions, my opinion has been much strengthened by the results both at El Paso and San Diego. I never viewed the enterprise in the light of procuring so much rain for so much money, though I am now convinced that the time will arrive when it will be possible to do so, and I am much in hopes that you will be enabled to prosecute your experiments until the practicability of the theory is demonstrated beyond any question.

You will doubtless be interested to know that the balloon which escaped you at San Diego, was found near the western boundary of our pasture, quite 40 miles, I should say, from where it ascended. It was still fairly well inflated, enough of the hydrogen having escaped to cause it to descend, I presume, and the half-burned fuse was still in place.

I hope it may happen that your investigations may again be pursued in this section, for I feel deeply interested in them, and I wish to say that we regard our contribution to the cause a most excellent investment.

Very truly yours,

G. W. FULTON, JR.

[Letter from Mr. Robert J. Kleberg, of the King Ranch.]

KING'S RANCH, COLLINS, NUECES COUNTY, TEX.,

December 22, 1891.

Your telegram of recent date, asking me to give you my views of past and future experiments in producing rainfall, came to hand a few days since, and I now comply with your request. As to past experiments, you know that I was not present at any of the experiments made by your party when you experimented at San Diego. I was here on the ranch, 27 miles to the southeast of the place where you operated, still I witnessed some of the results of your experiment on Saturday night, the last night that you experimented. I was here, and at about 21 o'clock that night, I was awakened out of a sound sleep by the shocks produced by the explosion of the balloons. It shook the building very perceptibly, so much so that everyone on the ranch here was awakened.

I went out and found the sky bright and clear; stars and moon shining brightly. Some of the men employed about the place had been up for some time trying to see or hear the explosions of your experiments, and they showed me the locality. I soon saw the flash of one of the exploding balloons, and exactly in a minute's time by the watch I felt the shock produced and noticed the shaking of the building I was in. I was in an observatory, about 50 feet from the ground, on top of a house. There was one small cloud visible in the sky at that time, and only one. This seemed to be about 5 acres large. It was a little to the east of San Diego and the point where I could see the explosions of the balloons. This cloud was alone, disconnected from any others; the stars were shining brightly beneath it in the sky, showing that it was not a part of a bank of clouds. This cloud was moving slowly from the east to the west, and we observed that every time a balloon exploded lightning seemed to flash in this little cloud, and they said that they had noticed it forming in the place where it then was.

I retired about 2 o'clock a. m., and at 4 a. m., I was again awakened by the rain falling on the roof of the house I was occupying. At 7, when I arose, but few clouds were visible and a dry "norther" or north wind was blowing. The rainfall at this place was very light, but a neighbor living 20 miles to the west of here and south of San Diego told me that on his ranch the best rain fell that night which had fallen there in three years. Now, I will further state in this connection, that, as all the "northers" we have had this winter, before that time and since, were "dry northers," I do not think that the clouds from which the rain fell that night or morning, were brought on by the "norther," but on the contrary were driven off by the same, and it seemed to me that the rain which

fell could fairly be claimed to have been produced by your experiment. So much for my views on the past. I do not think, however, that these experiments, which were made under the most adverse circumstances, have demonstrated, fairly and sufficiently, the theory whether or not rainfall can be produced by heavy concussions.

I do think, however, from what I could learn of the other experiments made by you at Midland and El Paso, and from what I saw or witnessed here of your experiments at San Diego, that the results were certainly encouraging to warrant our Government to make a liberal appropriation to be expended in further experiments to produce rainfall. There certainly is no subject of greater interest to our entire people than this, for in almost all portions of the Union has there been suffering from drought this year.

I do think that in less than ten years great progress will be made in this respect. Hoping to hear from you in reference to any steps which may be taken in this matter, I remain,

Yours truly,

ROBERT J. KLEBERG.

The foregoing extracts from letters are true copies of the originals.

S. ALLEN DYER,
First Lieutenant, Twenty-third Infantry, U. S. Army.

OBSERVATION OF ATTENDANT METEOROLOGICAL PHENOMENA.

I particularly invite your consideration of the following phenomena believed to have been observed:

(1) The hot and dry surface stratum of air in arid regions, exerting a repellent action upon any superior bodies or strata of air.

(2) The visible dissolving of clouds, showing the conversion or re-conversion of moisture into vapor upon contact of the clouds with the dry and warmer air of the surface stratum, the appearance being particularly striking when occurring while clouds are moving toward the observer.

(3) The visible precipitation from a cloud, without the precipitation reaching the ground.

(4) The greater rapidity of the surface currents, as compared with the higher currents, and the difference in direction of these currents from the surface currents and from each other at different altitudes.

(5) The mechanical effect of some of the explosions manifest in the whirling ring of ascending smoke attended by the peculiar moaning sound.

(6) The great force of the waves resulting from explosions, and the return wave resulting from contact of the explosion wave with a cloud.

(7) The precipitation from a moist cloud near by, from the blow of an explosion.

(8) The appearance of heavy cloud-formation, succeeding explosions, in the direction toward which the wind was blowing at the time of the explosions.

(9) The tendency of cloud-formation to develop at places on the horizon of the field of explosion, and the appearance of rain at these points gradually extending to the center, where it rained last when it rained at all.

DEDUCTIONS.

The few experiments which have been made, do not furnish sufficient data from which to form definite conclusions, or evidence upon which to uphold or condemn the theories of the artificial production or increase of rainfall by concussion. Experiments extending over a period of only a few months can scarcely be sufficient. It is only by a large number of

tests, with accurate noting of conditions and occurrences, that definite conclusions can be reached; and, if then it be ascertained to be a certainty that rainfall will be induced by explosions, that such production of rainfall can be reduced to an art, so as to effect precipitation at a predetermined place. What has been done so far is altogether preliminary; but with the benefit of the experience gained, I hope that the subject will be pursued. At the risk of being tiresome, I have embodied in my report the minutest details, in order that others who may follow me in this line of inquiry, may be fully advised as to what has preceded. It may be said, however, that the three principal tests which have been made, namely, at the "C" Ranch, Midland; at El Paso, and at San Diego, Tex. (all under conditions much more unfavorable than need ever be encountered in attempts to produce rainfall), supply testimony which would seem to point to the following inferences:

First. That when a moist cloud is present, which, if undisturbed, would pass away without precipitating its moisture, the jarring of the cloud by concussions will cause the particles of moisture in suspension to agglomerate and fall in greater or less quantity, according to the degree of moistness of the air in and beneath the cloud.

Second. That by taking advantage of those periods which frequently occur in droughts, and in most if not in all sections of the United States where precipitation is insufficient for vegetation, and during which atmospheric conditions favor rainfall, without there being actual rain, precipitation may be caused by concussion.

Third. That under the most unfavorable conditions for precipitation, conditions which need never be taken in operations to produce rain, storm conditions may be generated and rain be induced, there being, however, a wasteful expenditure of both time and material in overcoming unfavorable conditions.

COST.

In prosecuting the investigation in this matter, there has been a total expenditure, allowing the regular rates and prices for all transportation and other expenses of the party and the material (some of which, however, remains on hand for use in future experiments), of about \$17,000.

Of this amount there has been an actual expenditure, on the part of the Government, of about \$9,000, and assistance has been received from outside parties interested in the prosecution of the investigation, in the form of free railroad transportations, the furnishing of materials and labor free of charge, and the payment of expenses as stated in the report of Mr. Ellis, amounting to about \$6,017, to which should be added contribution by myself, and value of materials, labor, subsistence, etc., not specially itemized, amounting to perhaps some \$2,000 more; thus bringing to the work an amount nearly equal to the entire appropriation and enabling me to carry out the investigation to a much greater extent.

CONCLUSION.

For aid to the expedition at El Paso and San Diego, and for most efficient services rendered here, in Washington, appreciative thanks are due to Lieut. Dyer. This officer has been with me constantly during the preparation of this report and, by his knowledge and ability, his exact memory and strict attention to facts, he has enabled me to give a fuller statement of details than would otherwise have been possible.

In closing my report, I desire to disclaim (with the sole exception of a

denial by me, published in a prominent newspaper, of certain statements attributed to me by that newspaper), each and every statement which has appeared in any newspaper or periodical as coming from me; and I also desire to declare that all premature and undigested statements by any member of my party, especially an effusion in the nature of a public lecture here, assumptive of experience on the part of the lecturer unhad and of knowledge which could only be gained by the most complete experience, were unauthorized.

I forward herewith the maps of the Weather Bureau and the pamphlets to which I have referred.

Very respectfully,

R. G. DYRENFORTH.

WASHINGTON, *February 19, 1892.*

DEPARTMENT OF AGRICULTURE, OFFICE OF THE SECRETARY,
Washington, D. C., February 27, 1891.

SIR: You are hereby appointed special agent of this Department for "the making of experiments in the production of rainfall," in pursuance of the provision for the same in the appropriations for this Department for the current year, said appointment to continue until the 30th day of June, 1891.

You are hereby authorized to take full charge of the same, and incur any expense therefor that, in your judgment, is necessary, not exceeding the sum of \$2,000, less the expenses of Daniel Ruggles, of Fredericksburg, Va., the owner of a patent granted to him in 1880, covering the production of rainfall by artificial means, and who is in Washington at present, in consultation with this Department relative to the subject-matter of the experiments. At the proper time, when you get ready for the experiments, you will notify him to be present, and out of this sum will pay his traveling expenses and his expenses in Washington for a limited time. In other respects you are authorized to engage any experts, to purchase and transport any material, to pay traveling expenses of yourself and employés, as you may deem necessary in the premises for a complete trial of your experiments, all, as well as your own compensation, to be paid out of said \$2,000 on vouchers properly presented to this Department on or before the expiration of this commission.

Respectfully,

J. M. RUSK,
Secretary.

Mr. ROBERT G. DYRENFORTH,
Washington, D. C.

DEPARTMENT OF AGRICULTURE, OFFICE OF THE SECRETARY,
Washington, D. C., June 30, 1891.

SIR: Your appointment as special agent of this Department is hereby extended and continued for the fiscal year ending June 30, 1892. Your duties, as heretofore, will be making of "experiments in the production of rainfall," in pursuance of the provision for the same in the appropriations of this Department for the fiscal year ending June 30, 1892. You are hereby authorized to take full charge of said experiments and incur any expenses therefor that in your judgment are necessary, not exceeding the sum of \$7,000. You are authorized to engage any experts, to purchase and have transported any material, and make said experiments in any place you choose, and the traveling expenses of yourself and employés, your own compensation, and all expenses will be paid out of said fund. You are authorized to do the things you may deem necessary in the premises for a complete trial of your experiment; and all expenses herein authorized are to be properly presented, on vouchers, to this Department on or before the expiration of this commission.

Respectfully,

J. M. RUSK,
Secretary.

Mr. ROBERT G. DYRENFORTH,
Washington, D. C.

